PM_{10} MODELING BY USING TIME SERIES ANALYSIS IN OIL AND GAS INDUSTRY

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By

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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr Nurul Izma Binti Mohammed)

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JANUARY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMAD ASHRAF BIN NAHARUDIN

ABSTRACT

High particulate event has been caught to attention for a long time as it cannot be controlled by humans to reduce it. However, high particulate event usually can be predicted as it is categorized as air pollution which means it is caused by human activities such as open burning, motor vehicles, and industrial activities. As time goes on, it can be generalized that high particulate is most likely to occur during the dry season, which is from February to April due to several meteorological factors such as wind speed, humidity and temperature. In this study, the main aim is to monitor the concentration of the pollutant which is particulate matter with aerodynamic diameter less than 10 micrometer (PM_{10}) and it will be focused on oil and industry area. This is to allow understanding in the concentration pattern of the pollutant in industrial area particularly in oil and gas industry. Through that, the meteorological factor that may affect the occurrence of high particulate event can be identified and will be able to relate with the occurrence of high particulate event. The sample of pollutant was collected from various locations and it was collected hourly for 24 hours per day for 3 years that is from 2008 to 2010, using the equipment Aeroqual AQM 60. From the analyzed data, the concentration of PM_{10} in oil and gas industry was found to exceed the Malaysian Ambient Air Quality Guidelines (MAAQG) that has been set by the Malaysia's Department of Environment (DOE). The meteorological factor such as humidity and ambient temperature was determined and is believed to have effects on the PM_{10} concentration in oil and gas industry. It was concluded that there are relation between the pollutants and meteorological factor.

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CHAPTER 1

INTRODUCTION

1.1. Background of study

Oxford dictionary defines “air” as the invisible gaseous substances surrounding the earth atmosphere. Air is one of the major needs required by living things in order to live on the earth. Generally, air is the mixture of gases and contains water vapor (Shakhashiri, 2007). It is found that the dry air compositions, where water vapor is excluded, contains about 78 % of nitrogen (N_2), 21 % of oxygen (O_2), and 1 % of other gases such as carbon dioxide (CO_2) and inert gases such as argon (Ar), neon (Ne), helium (He), krypton (Kr) and xenon (Xe) (Shakhashiri, 2007). The water vapor was excluded from the air composition because the composition of water vapor varies due to locations, altitudes, temperature, humidity, and time. Table 1 elaborates the composition of dry air in the earth atmosphere.

Table 1: Compositions of Dry Air (Shakhashiri, 2007)

Substance	**Percentage by volume (%)**
Nitrogen, N_2	78.08
Oxygen, O_2	20.95
Argon, Ar	0.93
Carbon dioxide, CO_2	0.033
Neon, Ne	0.0018
Helium, He	0.00052
Methane, CH_4	0.0002
Krypton, Kr	0.00011
Nitrogen(I) oxide, N_2O	0.00005
Hydrogen, H_2	0.00005
Xenon, Xe	0.0000087
Ozone, O_3	0.000001

The air quality should be monitored in order to detect changes in the ambient air quality status that may cause harm to human health and the environment (DOE, 2014). In Malaysia, Department of Environment (DOE) has given a guideline named Malaysian Ambient Air Quality Guideline (MAAQG). MAAQG is a guideline of air pollutants concentration upon maintaining a good air quality. Table 2 states the MAAQG set by the DOE.

Table 2: The Malaysian Ambient Air Quality Guideline (DOE, 2014).

Pollutant	**Averaging Time**	**Malaysian Guidelines (Concentration)**	
		ppm	($\mu g/m^3$)
Ozone (O_3)	1 Hour 8 Hours	0.10 0.06	200 120
Carbon Monoxide (CO)	1 Hour 8 Hours	30.0 9.0	35* 10*
Nitrogen Dioxide (NO_2)	1 Hour 24 hours	0.17 0.04	320 10
Sulphur Dioxide (SO_2)	1 hour 24 Hours	0.13 0.04	350 105
Particulate Matter (PM_{10})	24 Hours 12 Months		150 50
Total Suspended Particulate (TSP)	24 Hours 12 Months		260 90
Lead (Pb)	3 Months		1.5

Note:
** (mg/m^3)*

There are 2 ways of monitoring the ambient air quality which are; Continuous Air Quality Monitoring (CAQM), and Manual Air Quality Monitoring (MAQM).

Continuous Air Quality Monitoring (CAQM)

DOE monitors the ambient air quality of Malaysia through 52 network stations that is strategically located in residential areas, traffic areas, and industrial areas (DOE, 2014). CAQM is meant to monitor automatically the air quality, collecting data/measure data continuously in 24 hours a day. DOE states that the CAQM stations were divided into 5 categories which are Industrial, residential, traffic, background, and particulate matter with size less than 10 micrometers (PM_{10}) stations. Table 3 shows the parameters measured in CAQM stations.

Table 3: Parameters measured in 5 categories of CAQM stations (DOE, 2014).

Category	**Sulphur Dioxide**	**Nitrogen Oxide**	**Carbon Monoxide**	**Ozone**	**Hydro-carbon**	**PM_{10}**	**UV**
Industrial	x	x	-	-	x	x	-
Residential	x	x	x	x	x	x	x
Traffic	x	x	-	x	x	x	-
Background	x	x	x	x	x	x	x
PM_{10}	-	-	-	-	-	x	-

Manual Air Quality Monitoring (MAQM)

MAQM measurement is manually collected and is delivered to the laboratory for analysis (DOE, 2014). It uses High Volume Sampler that is located at 19 sites to collect pollutants such as TSP, PM_{10}, and heavy metals such as lead mercury, iron, sodium, and copper. The samples are measured once every six days.

The air can be polluted when the concentrations of pollutants are in huge amount and exceed the guideline set by DOE. Daly et al. (2007), defines "air pollution" is the emission of man-made (anthropogenic) into the air as it will cause alteration of chemical composition of the natural atmosphere. Most of the time, the emissions (pollutants) are harmful to the environment which then brings negative impact towards the environment and the air quality. The main sources of pollution in Malaysia are; industries activities, development activities, motor vehicles, power generation, land clearing, and open burning and forest fires (Afroz et al., 2003; Gemenetzis et al., 2006; Norela et al., 2013; DOE, 2014).

There are two type of pollutants that are primary pollutants and secondary pollutants. Primary pollutants are substances directly emitted into the air from sources while the secondary pollutants are formed in the atmosphere due to chemical transformation of the primary pollutants (Naresh et al., 2006; Daly et. al., 2007). In Malaysia, the primary pollutants are CO, and PM_{10}, while the secondary pollutants are SO_2, NO_2, and O_3 (DOE, 2014).

Levy et al. (2013) reported that the effect of a change in emissions of primary pollutants can be predicted with relative accuracy. However, secondary pollutants such as O_3 is not always possible. This is due to the nonlinear relations in the photochemical productions of O_3 in troposphere between its precursors that are nitrogen oxides (NO_x) and volatile organic compounds (VOC). These makes it difficult to predict the prospective outcome of any reduction measures. Geddes et al. (2009) added that this pollutant is strongly influenced by meteorological processes. Geddes et al. (2009) reported that the province of Ontario had an economic losses due to human health impact and agricultural damaged caused by this secondary pollutants. It is concluded that secondary pollutants leads to great negative impacts to the environment.

Particulates matters that usually cannot be seen by naked eye are suspended in the atmosphere in high concentration will lead to high particle event (DOE, 2014). The source of pollutants are vehicle combustions, power stations, industrial fuel burning, industrial production processes, domestic and commercial furnaces, and open burning at solid waste disposal sites (Afroz et. al. 2003). Norela et al. (2013) added

that agricultural practices such as biomass burning and peat soils burning also contribute to air pollution.

PM_{10} is a particulate matter with particle size with less than 10 micrometers (Mohamed et al. 2011; Ul-Saufie et al. 2013; DOE, 2014). PM_{10} has been a common cause of air pollution, particularly the cause of high particle event, in Malaysia with the highest concentration is observed frequently during the dry season that is due to the South West Monsoon between the month of May and September (Mohamed, 2011; Shaadan et al., 2012). One of the reason of the event to occur is due the biomass burning in Sumatera, Indonesia where significant particulate matter, which consist of PM_{10} were transported by the south-west monsoon wind towards neighboring country particularly Malaysia (Afroz et al., 2003).

Shaadan et al. (2012) reported that PM_{10} will lead to serious effects on human health especially such as lung infection, asthma, and eye-related illness. It was reported that severe high particle event had occurred in 1983, 1990, 1991, 1994, 1997, 1998, 2005, 2006, and 2013 (Tayeh et. al, 2012; Norela et. al., 2013).

Air pollution can be monitored through the Air Pollution Index (API) as the indicator in monitoring the air quality (DOE, 2014). The API is calculated based on the average parameters of the 5 major pollutants mentioned. In Malaysia, Department of Environment (DOE) has set the API for the country. Table 4 describes the API and its status for Malaysia.

Table 4: List of API and its status (DOE, 2014).

API	**Status**
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very unhealthy
> 300	Hazardous
> 500	Emergency

1.2. Problem Statement

The effects of air pollution is getting severe and one of the major pollutants is the particulate matter with less than 10 micrometer, PM_{10} (Mohamed et al. 2011; Ul-Saufie et al. 2013; DOE, 2014). The severity of this pollutant cause high particulate event to occur, which then leads to negative effects such as asthma, lung infections, and eye infections on the environment as well as living things especially humans.

It was found that the urban and industrial areas have higher concentrations of PM_{10} due to the transportation, industrial activities, and the geographical position (Mohamed et al. 2011; DOE, 2014).

In Malaysia, the dispersion of PM_{10} are widely studied in industrial areas, where busy cities and towns are located, while in other country, they had conducted the study of dispersion of pollutants for indoor emissions. However, there are only a few studies done on the emissions of pollutants in the oil and gas industries in the world, which currently a study had been conducted in Texas to compile the inventory of pollutant emissions, and there was no study done regarding on PM_{10} dispersion in the oil and gas industries in Malaysia. It is believed that oil and gas industries could have also contributed in air pollution especially the emissions of PM_{10} (The Eastern Research Group Inc., 2007). Therefore, it is crucial to study the dispersion of PM_{10} in oil and gas industries.

Thus, the PM_{10} dispersion behavior can be identify and analyze. Therefore, the solutions can be formed to reduce the negative effects and the contributions of PM_{10} towards high particulate event.

1.3. Objectives

1. To monitor the concentration of PM_{10} in oil and gas industry.
2. To determine the meteorological factor that leads to high particulate event.
3. To study the relationship of PM_{10} and meteorological factor.

1.4. Scope of Study

This study will measure the pollutant of PM_{10} concentration at oil and gas industry. The focused areas of oil and gas industry for the study are located in Kerteh, Miri, Jerantut, Paka, and Bintulu.. The sample data was obtained from Department of Environment (DOE), Malaysia for 3 years period, from 2008 to 2010, for 24 hours per day.

CHAPTER 2

LITERATURE REVIEW

2.1 Particulate matter

Particulate matter (PM) is a complex mixture of extremely small solids and liquid droplets (Hanapi et al., 2012). Hanapi et al. (2012) reported that PM contains organic chemicals, metals, soil or dust particles, and acids such as nitrates and sulfates. The mass and compositions of PM are divided as course particles and fine particles. Fine particles are particles with the size that is less than 2.5 micrometers, which is called $PM_{2.5}$ while coarse particle are particles with larger size, which includes PM_{10}.

There are several common sources of PM that contributes to air pollution towards the environment such as agricultural waste burning, construction and aggregate processing, soil dust, paved road dust, solid waste open burning, industrial diesel generators, coal combustion, kerosene generators, and fuel oil combustion in boilers (Gemenetzis et al., 2006). Patil et al. (2013) find the similar sources of PM in India.

Both $PM_{2.5}$ and PM_{10} are particles that can pass through throat and nose, and enters the lungs. Once inhaled, these pollutants can cause serious health effects (Hanapi et al., 2012). Gemenetzis et al. (2006) reported that PM_{10} have been shown to have significant pertinence to lung disorders, respiratory and cardiovascular diseases while $PM_{2.5}$ will usually lead to deaths, cardiopulmonary diseases and lung cancer.

2.2 Particulate Matter (PM_{10})

PM_{10} is a particulate matter with an aerodynamic diameter with less than 10 micrometer, which can be a suspension of solid, liquid or a combination of both solid and liquid particles in the air (Ul-Saufie et al., 2013). Mohamed et al. (2011) stated that PM_{10} had been received extensive attention as it triggers harm to human health as well as the environment. Juneng et al. (2009), Mohamed et al. (2011) and Shaadan et al. (2012) reported that PM_{10} was found to be remarkably high at urban areas and during dry seasons. During dry season, the weather is most likely to be low wind speed, low dewpoint, which causes less horizontal dispersion of pollutants and dry weather will tend to accumulate the pollutants in the air (Kim Oanh et. al., 2011).

There are five major PM_{10} emissions in Malaysia that are motor vehicle exhaust, heat and power plants, industrial sources, and open burning (DOE, 2014). Ul-Saufie et al. (2013) concluded that the prominent sources are mostly from heavy traffics and industries.

Gemenetzis et al. (2006), Hanapi et al. (2012), and Ul-Saufie et al. (2013) reported saying that long exposure towards PM_{10} leads human to health problem such as respiratory problems, damage to lung tissue, cancer, cardiovascular diseases and premature death.

2.3 Meteorological effect

Kim Oanh et. al. (2011) stated that air pollution formation depends on the emission source intensity and the meteorological conditions such as stagnant air. It is found that at certain topography, such as bowl-shaped valley, restricts the pollution dispersion in the environment. Kim Oanh et. al. (2011) conducted a study in Chiangmai city, which is located in northern capital of Thailand regarding air pollution particularly high particulate event with meteorological conditions.

From the study conducted, a few variables of meteorological conditions were selected, which are cloud cover, dewpoint temperature, wind direction index, wind speed, and sea level pressure. It is found that high amount of PM_{10} with stagnant air

conditions, particularly with clear sky, light wind, low dewpoint were observed in the formation of ground-based radiative inversion.

Figure 1 illustrates the regional surface of the synoptic charts with inserted windrose. There were 4 different patterns namely pattern 1, pattern 2, pattern 3, and pattern 4 upon conducting the study with different dates but with the same time for 8 years (2001 - 2008).

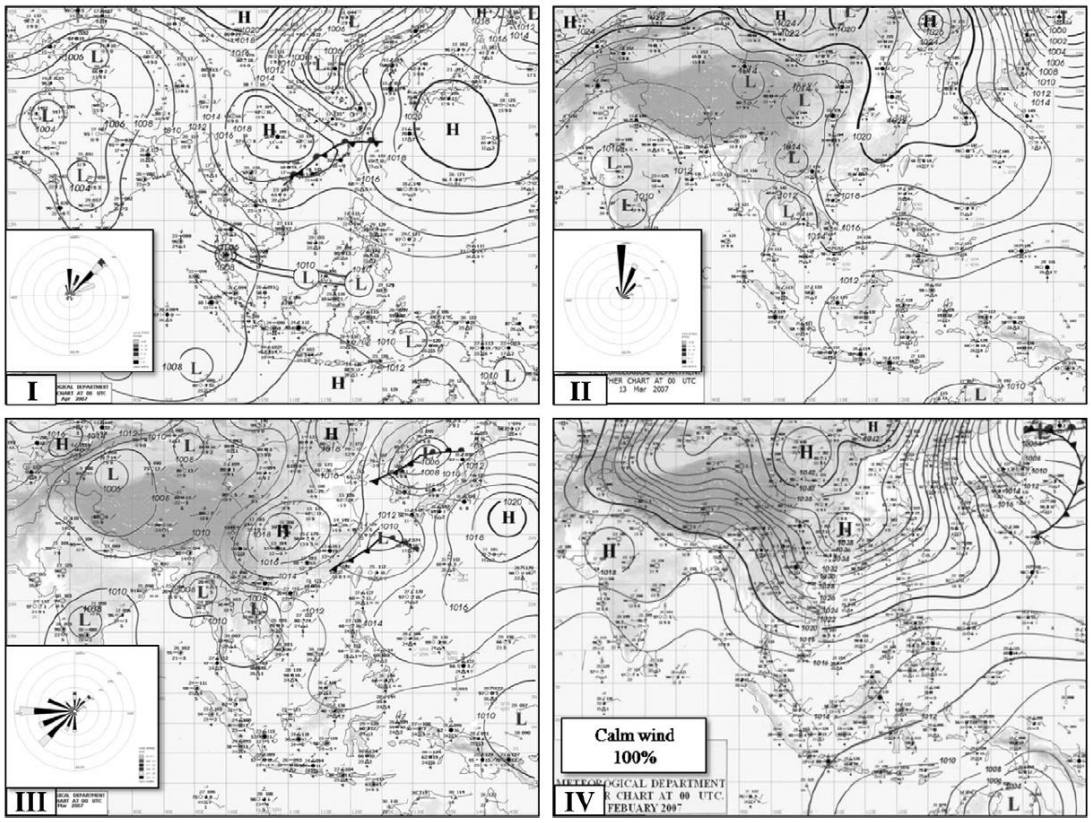
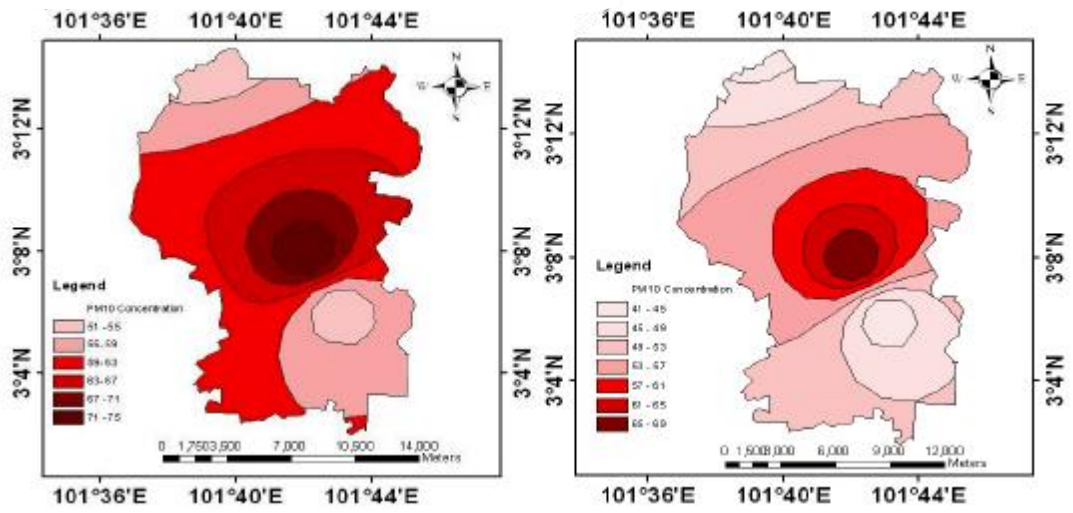


Figure 1: Example of regional surface synoptic charts at 07.00 am LST with inserted windrose: (I) Pattern 1 (30 April 2007), (II) pattern 2 (13 March 2007), (III) pattern 3 (27 march 2007), (IV) pattern 4 (1 February 2007). (Kim Oanh et. al., 2011)

As a conclusion for this study regarding meteorological conditions, it is proven that meteorological conditions do affect the air pollution formation particularly high particulate event, from this study it is most likely referring to pattern 2. Typically, high particulate event will occur during dry seasons due to low of dewpoint where there are weak wind and strong inversion, which indicates less horizontal dispersion of the pollutants.

2.4 PM_{10} dispersion in industrial areas

PM_{10} were among the primary pollutants that have gotten extensive attention as it causes most of health problems. PM_{10} can be found mainly on anthropogenic activities especially in industrial areas due to rapid growing of industrialization (Mohamed et. al., 2011). Jamil et al. (2011) had done studies on PM_{10} dispersion in Kuala Lumpur (KL), Malaysia specifically at Victoria KL, Cheras KL, and Gombak. It is found that the amount of PM_{10} is larger during weekdays as compared to weekends. Jamil et al. (2011) added that the concentrations of PM_{10} increment occurs from 6.00 a.m. to 8.00 a.m. and from 4.00 p.m. to 8.00 p.m. This concludes that the amount of PM_{10} is influenced by the motor vehicles activity or the traffic volume of the study area as those time are the peak-hours of working where people go to work and go back home respectively. Figure 2 illustrates the surface maps of PM_{10} mass in Kuala Lumpur for both weekdays and weekends.



(a) (b)

Figure 2: (a) Higher amount of PM_{10} mass at the beginning of the week (Monday),
(b) Relatively lower amount of PM_{10} mass during weekend (Saturday) (Jamil et. al., 2011)

On the other hand, the PM_{10} dispersion in industrial areas have slightly different pattern than mobile activity. Using the methods of probability distributions, Mohamed et al. (2011) were able to fit the air pollutant concentrations including Weibull distribution, lognormal distribution, gamma distribution, and Rayleigh distribution. Mohamed et al. (2011) have studied the goodness-of-fit for selected probability distributions by using performance indicators such as mean absolute error (MAE), root means error (RMSE), index of agreement (d_2), bias (B), normalized absolute error (NAE), prediction accuracy (PA) and coefficient of determination (R^2). However, the study uses the coefficient of determination (R^2) to determine the correlation coefficient. The result stated that R^2 for Victoria KL, Cheras KL, and Gombak KL are 0.594, 0.332, and 0.359 respectively. Meanwhile, Mohamed et al. (2006; 2011) had done the study for PM_{10} dispersion in industrial areas at Nilai and Shah Alam.

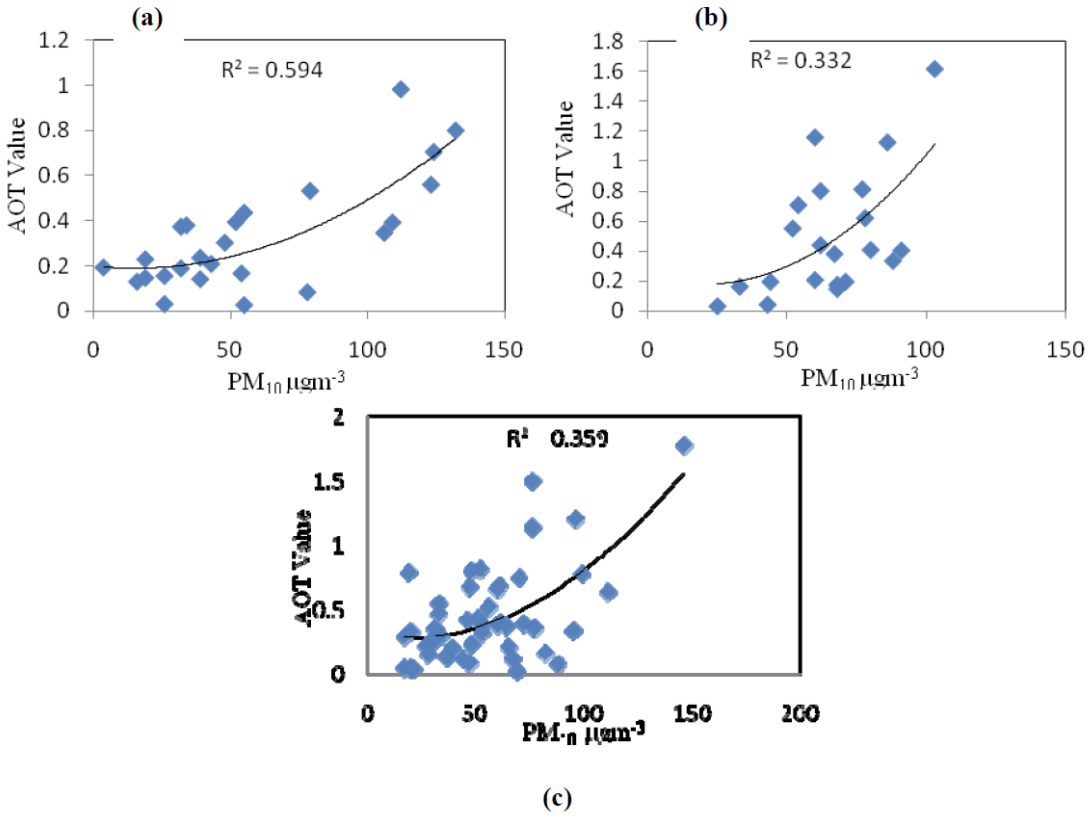


Figure 3: (a), (b), and (c) The scatter plots of non-linear correlation coefficient for Victoria KL, Cheras KL and Gombak KL stations respectively. (Jamil et. al., 2011)

2.5 PM_{10} in oil and gas industries

It is believed that there are PM_{10} emission in the oil and gas industries, which will then causes the air to be polluted. The Eastern Research Group Inc. (2007) made a study of emissions of pollutants from the oil and gas production facilities. The study made was on a purpose to compile the emission inventory for onshore oil and gas exploration and production in Texas and for offshore production platforms (within 25 miles of the Texas coast) for the base year of 2005.

The Eastern Research Group Inc. reported that the oil and gas industry may have lost of sources, which contributes the emissions of pollutants. However, the larger source such as refineries, bulk plants, and large transmission/ distribution stations were identified generally and is treated as the major point sources. In the study made by the Eastern Research Group Inc. (2007), the oil and gas source categories were divided into 3 major groups, which are exploration sources, production sources, and offshore stationary sources.

From the study done, the pollutants that were identified from the 3 major sources categories are carbon monoxide (CO), nitrogen oxide (NO_x), volatile organic compound (VOC), sulfur dioxide (SO_2), and particulate matter (PM), which includes PM_{10} and $PM_{2.5}$.

It is found that there were about 96 % of emissions for PM_{10} in oil and gas industries. In drilling rig engines, there were 53.8 % of emissions and 42.5 % of emissions from the compressor engines. Both of these sources were due to the onshore exploration and production. However, on the offshore platform, the emission of PM_{10} contributed approximately 1 %.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This study is to model the dispersion of PM_{10} in the oil and gas industries. The study area will be done at several oil and gas industry area which are Paka, Jerantut, Kerteh, Miri and Bintulu. However, not all of the stations are to be discussed, only the critical one will be discussed. Figure 4 shows the location of the study area for the critical ones which is at Kerteh.

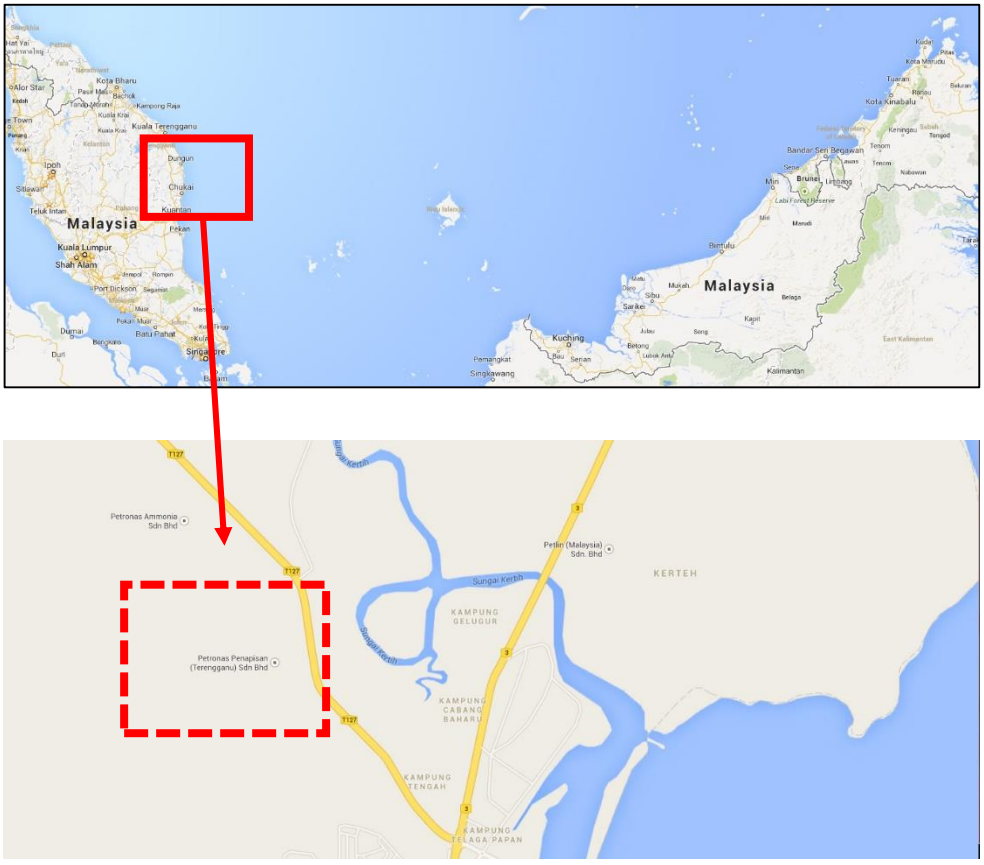


Figure 4: Location of study area.

3.1.1 Key Milestone

The following is the key milestone for FYP 1

No.	Detail Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection Project Topic														
2	Preliminary Research Work														
3	Submission of Extended Proposal														
4	Proposal Defence														
5	Project work continues														
6	Submission of Interim Draft Report														
7	Submission of interim report														

The following is the key milestone for FYP 2

No.	Detail Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project work														
2	Submission of progress report														
3	Project work continues														
4	Pre- SEDEX														
5	Submission of draft report														
6	Submission of dissertation (soft bound)														
7	Submission of technical paper														
8	Oral presentation														
9	Submission of project dissertation (Hard bound)														

Legend

Process

Key Milestone

3.2 PM_{10} concentration analysis

3.2.1 Time series analysis

Time series analysis is a collection of observations of well-defined data items obtained through repeated measurements over time. The main aim of time series analysis is to describe the movement history of a particular variable in time. Time series analysis of air pollution environmental levels involves the identification of long-term variation of the mean and or periodic components. Thus, time series analysis helps to understand better of the cause and effect relationships of the study.

In this study, PM_{10} dispersion will be monitored in hourly basis. Therefore, the dispersion of PM_{10} will be observed hourly per day and hence, should be able to model the dispersion in the variation of time. By using this analysis, the data produced should be reliable in terms of statistics behavior.

3.3 Measurement of PM_{10}

Concentration of PM_{10} was obtained from DOE, where the equipment used is Aeroqual AQM60 Environmental Station as shown in Figure 3. This is a custom-built ambient air quality instrument. This instrument is able to measure common air pollutants such as O_3, NO_2, CO, SO_2, as well as PM_{10} and $PM_{2.5.}$ It can also measure meteorological parameters such as temperature, humidity, wind speed, and directions. This instrument comes with a software that will be able to retrieve the data sample collected by the instrument. This instrument can determine the concentration of PM_{10} by forwarding light scattering via a laser diode optical sensor to detect, size, and count the particles in eight digital bins.

Figure 5: Aeroqual AQM60 Environmental Station

However, the data obtain from DOE is only from 2008 to 2010 only due to unavailable data in other years. The sampling data was recorded daily in hourly basis. The data then will be tabulated and a time series model is produced to analyze the study area.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The pollutant particulate matter (PM_{10}) at all the selected stations had been analyzed throughout year 2008, 2009, and 2010 starting from January until December. The sampling was taken on an hourly basis every day. In order to relate the pattern of the pollutant concentration, data of meteorological parameters were collected too such as humidity and ambient temperature. The data collected is also on hourly basis daily. The data collected was then tabulated using Microsoft Excel and graphs were plotted to observe the pattern of the pollutant concentration in relation with the meteorological parameters. Only Station B will be discussed on the pattern of the pollutant's concentration. The remaining sampling will be presented in Appendix A.

4.2 Concentration of PM_{10}

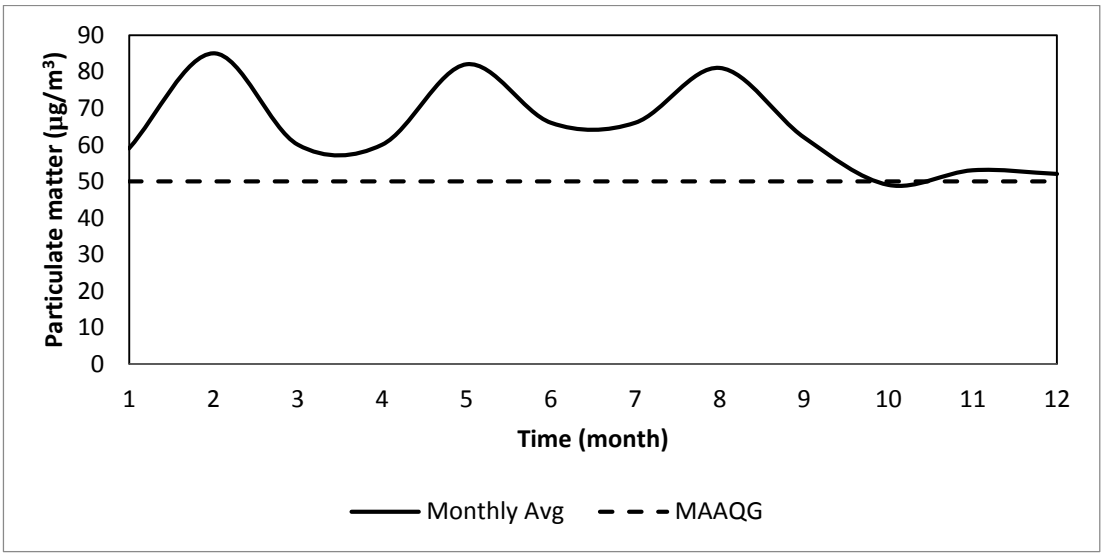


Figure 6: Concentration of PM_{10} for the year 2010 at Station B

Figure 6 illustrates the concentration of PM_{10} for the year 2010 at Station B. The concentration of PM_{10} is found to fluctuate according to time. The concentration of PM_{10} on January was 59 $\mu g/m^3$ and increased to 85 $\mu g/m^3$ upon February which marks the highest peak value of the year. This is mainly due to the dry season that Malaysia is experiencing. It is found that in the month of January – March the ambient temperature is relatively high as compared to other months. High particulate event is most likely to happen within this period due to high concentration of PM_{10}. The concentration then decreased in March. In May, the concentration increased to another peak value and decreased when approaching June. The concentration is then increased again to another peak value in the month of August. During this period, Malaysia is experiencing El Niño, which causes dry environment in Malaysia. Due to the dry environment, there are high tendency of forest burning in a large scale which then leads to high particulate event. Not only forest burning in Malaysia, Malaysia is also affected by the forest burning be neighboring country in Indonesia. The pollutants mainly PM_{10} was transported due to the monsoon wind (Yusof et. al., 2008: Juneng et. al., 2011). The concentration then decreased from September onwards and ranged from 50 - 60 $\mu g/m^3$ until December. The north-east monsoon season cause the decrement of the PM_{10} concentration from September to December. This is because Malaysia is experiencing rainy season during this period that could wash away the pollutants trapped in the atmosphere.

Generally, it is found that the concentration of PM_{10} throughout 2010 exceeds the standard limit of MAAQG which is at 50 $\mu g/m^3$ for averaging time of 12 months which can harm the community nearby.

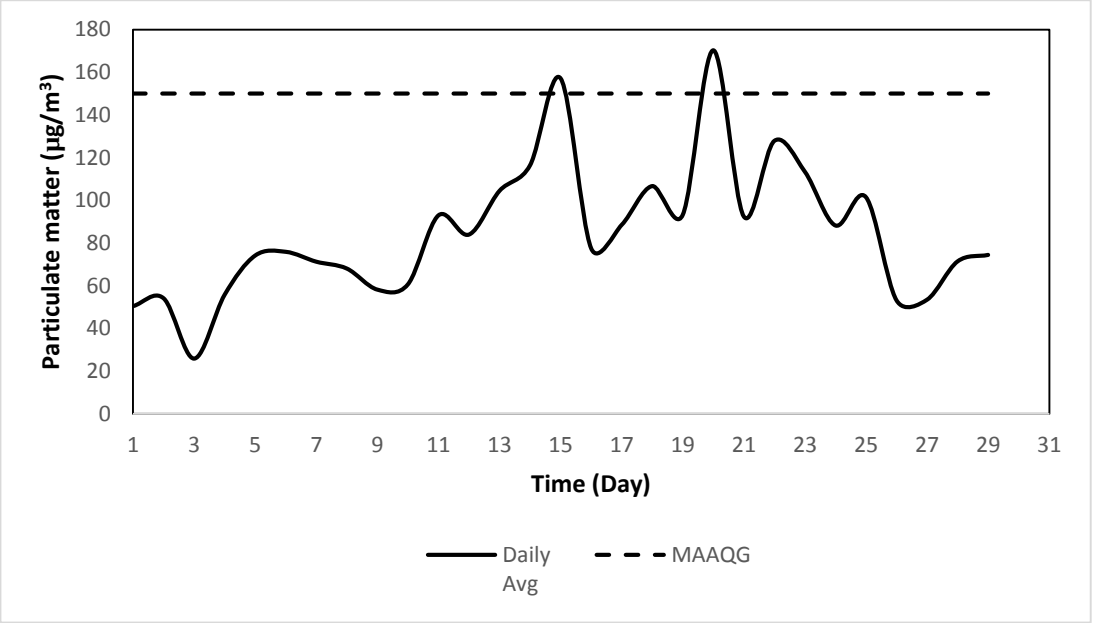


Figure 7: Concentration of PM_{10} in the month of February 2010 at Station B

Figure 7 demonstrates the daily average concentration of PM_{10} in the month of February. It is shown that the concentration of PM_{10} is quite low in the early of February. However, it increases as it approached the mid of the month. It is then decreased upon approaching the end of the month. From Figure 7, it is shown that the concentration of PM_{10} at day 15 and day 21 exceeded the standard limit MAAQG which is 150 µg/m^3 for average time of 24 hours.

4.3 Meteorological Parameters

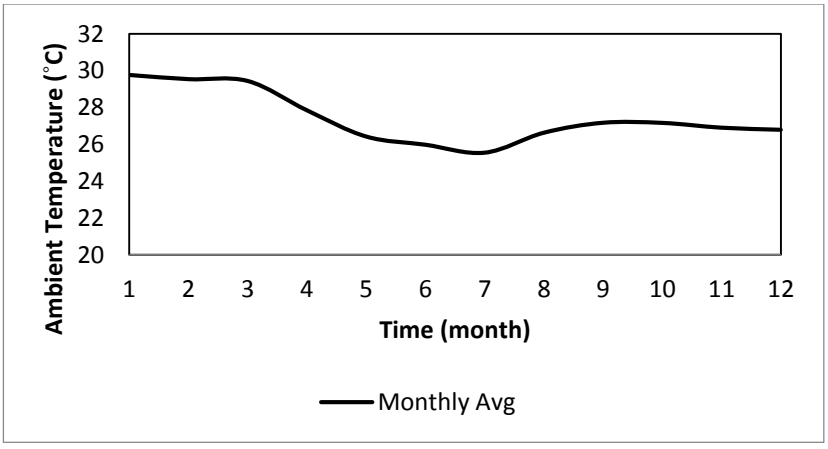


Figure 8: Ambient temperature of the year 2010 at Station B

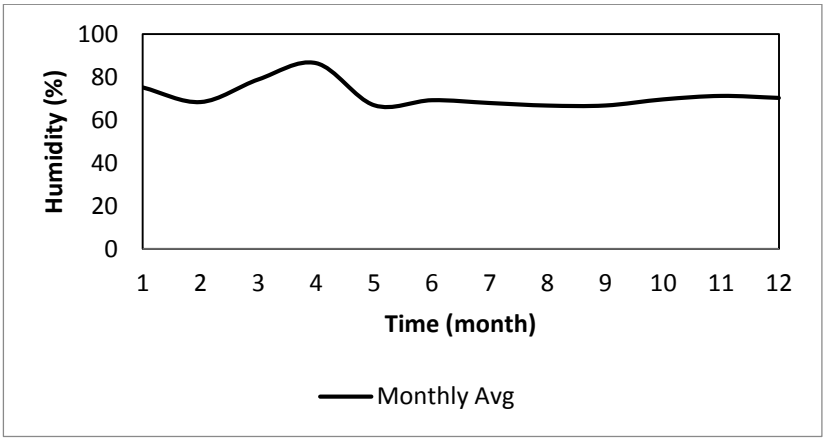


Figure 9: Humidity of the year 2010 at Station B

The ambient temperature at Station B is as shown in Figure 8. The temperature decreases from 30 to about 26 ˚C from January to July. It is then averaged at 27 ˚C from the month of August onwards. As mentioned in section 4.2, The high temperature that from January to March is due to the dry season Malaysia is experiencing which leads to high particulate event especially in February.

The humidity at Station B is averaging at a range of 60 – 70 % throughout the year as shown in Figure 9. However, in the month of April, it is shown that there's increase of humidity which is at 86 %. Malaysia is considered very humid. With high humidity, the pollutants are trapped and will remain within the atmosphere. This is one of the factor that causes high particulate event. However, the effect of humidity is less significant as compared to the ambient temperature (Yusof et. al., 2008).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Air pollution is a serious issue especially when it affects the health of human and other living creatures. Major pollutants such as PM_{10} that are present in high concentration leads to high particulate event thus worsen the air quality of the environment. There are several sources of pollutants emission such as from the vehicles, industrial area, and forest burning. This study is done to study the PM_{10} concentration in oil and gas industry. From the study, PM_{10} concentration in oil and gas industry exceeds the MAAQG at the average time of 12 months with the highest concentration measured in the months of February. Meteorological factor such as ambient temperature and humidity do affect the PM_{10} concentration. Thus, it can be concluded that the PM_{10} concentration in oil and gas industry is also affected by meteorological factor which leads to high particulate event. Therefore, the objectives of the study is achieved.

Throughout the study, it is best if the results obtained from the oil and gas industry can be compared with the general industrial area. This comparison is to show the differences in PM_{10} concentrations and to show which area is more critical. Thus, the MAAQG can be revised either to add category specifically for oil and gas industry or to reduce the current MAAQG set.

REFERENCES

1. Afroz R., Hassan M.N., Ibrahim N.A., (2003), Environmental Research 92, *Review of air pollution and health impacts in Malaysia*, 71-77.

2. Daly A., Zannetti P., (2006), *An Introduction to Air Pollution – Definitions, Classifications, and History*. The EnviroCamp Institute, Fremont, USA

3. Department of Environment, (2014) *Air Quality*, retrieved on 10th February 2014 from http://www.doe.gov.my/webportal/en/info-umum/kuality-udara/

4. Department of Environment, (2014) *General Information of Air Pollutant Index*, retrieved on 10th February 2014 from http://www.doe.gov.my/webportal/en/info-umum/bahasa-inggeris-general-information-of-air-pollutant-index/

5. Eastern Research Group, Inc. (2007, August 31), *Emission from Oil and Gas Production Facilities.*

6. Geddes J.A., Murphy J.G., Wang D.K., (2009), Atmospheric Environment 43, *Long term changes in nitrogen oxides and volatile organic compounds in Toronto and the challenges facing local ozone control*, 3407-3415.

7. Germenetzis P., Moussas P., Arditsoglou A., Samara C., (2006), *Mass Concentration and Elemental Composition of Indoor $PM_{2.5}$ and PM_{10} in University Rooms in Thessaloniki, northern Greece.*

8. Hanapi N., Din S.A.M., (2012), *A Study on the Airborne Particulates Matter in Selected Museums of Peninsular Malaysia*, Elsevier Ltd.

9. Juneng L., Latif M.T., Tangang F., (2011), *Factors Influencing the Variations of PM_{10} Aerosol Dust in Klang Valley, Malaysia During Summer*. Atmospheric environment 45. 4370-4378.

10. Kim Oanh N.T., Leelasakultum K. (2011), *Analysis of meteorology and emission in haze episode prevalence over mountain-bounded region for early warning*, Science of The Total Environment, Volume 409, Issue 11, Pages 2261-2271, ISSN 0048-9697

11. Levy I., (2013), *A National Day with Near Zero Emissions and its Effect on Primary and Secondary Pollutants.*

12. MdYusof N.F.F.,, Ghazali N.A., Ramli N.A., Yahaya A.S., Samsuddin N., Al Madhoun W., (2008) *Correlation on PM_{10} Concentration and Weather in Concjunction with Haze Event in Seberang Perai, Penang.*

13. Mohamed N.M., Tan C.Y., Abdullah M.M.A.B., Ramli N.A., Yahaya A.S., (2011), *Modelling of PM_{10} Concentration in Industrialized Area in Malaysia: A Case Study in Nilai*.

14. Mohamed N.N., Abdullah M.M.A., Tan C.Y., Ramli N.A., Yahaya A.S., Fitri N.F.M.Y., (2011), *Modelling PM_{10} Concentration for Industrialized Area in Malaysia: A Case Study in Shah Alam.*

15. Norela S., Saidah M.S., Mahmud M., (2013), *Chemical Composition of the Haze in Malaysia 2005.*

16. Patil R.S., Kumar R., Menon R., Shah M.K., Sethi V., (2013), *Development of Particulate Matter Speciation Profiles for Major Sources in Six Cities in India.*

17. Shaadan N., Deni S.M., Jemain A.A., (2012), *Comparing the Severity of PM_{10} using Functional Descriptive Statistics: A Case Study in Klang Valey*.Journal of Statistical Modeling and Analytis. Vol. 3 No. 1, 1-10.

18. Shakhashiri (2007, Nov), *Gases of the Air.*, Chemistry 103-1.

19. Tayeh S.M.O., Ramli N.A., (2012), *High Particulate Events in Southeast Asia and Their Impacts: Review.*

20. Ul-Saufie A.Z., Yahaya A.S., Ramli N.A., Rosaida N., Hamid H.A., (2013), *Future Daily PM_{10} Concentrations Prediction by Combining Regression Models and Feedforward Backpropagation Models with Principle Component Analysis (PCA).*

APPENDIX

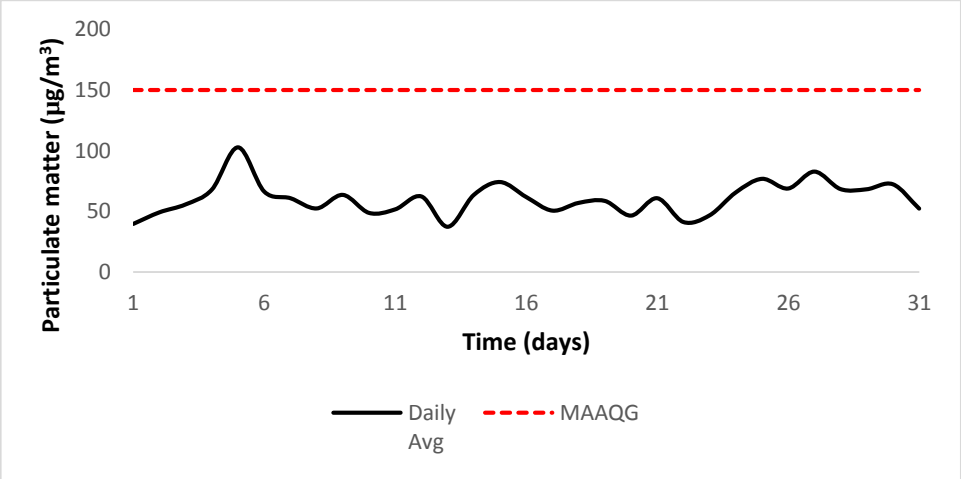


Figure A-1: Concentration of PM_{10} versus time in March 2010 at Station A

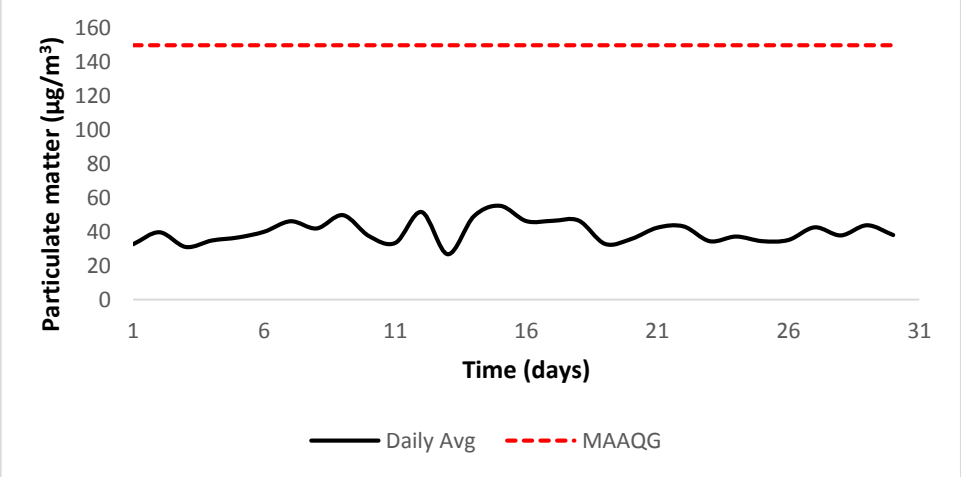


Figure A-2: Concentration of PM_{10} versus time in April 2010 at Station A

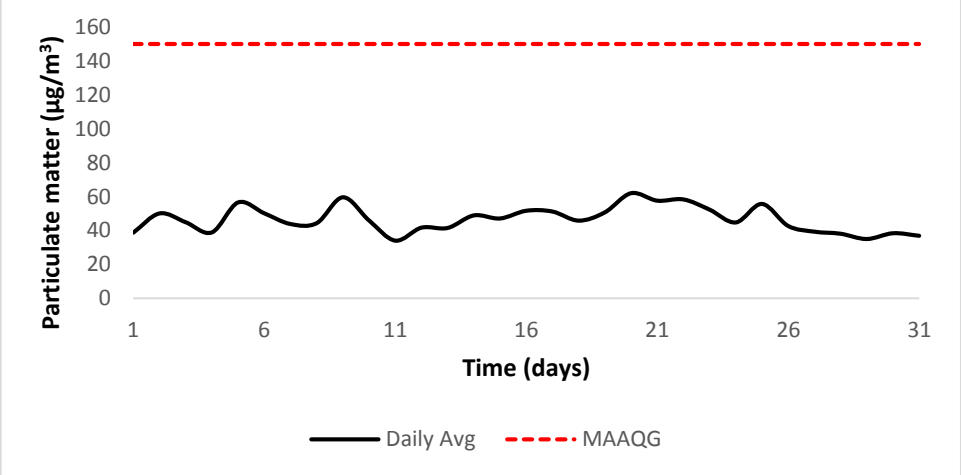


Figure A-3: Concentration of PM_{10} versus time in May 2010 at Station A

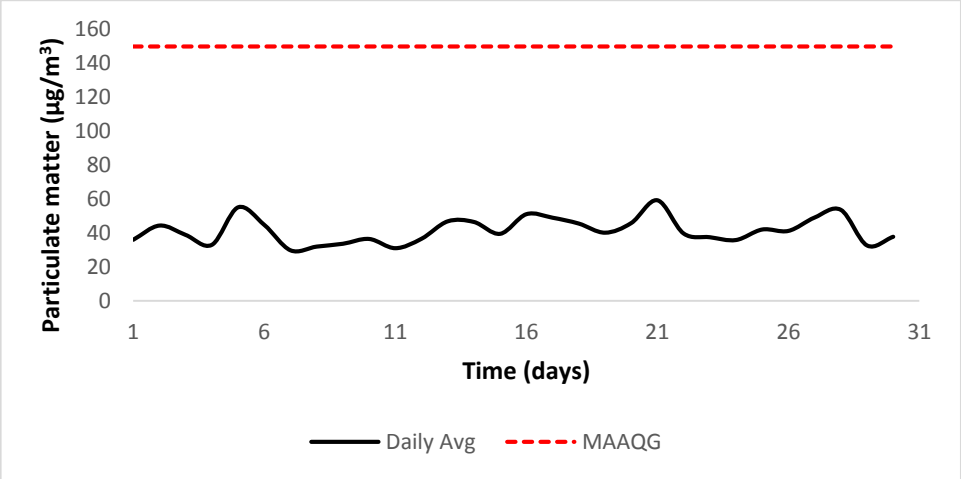


Figure A-4: Concentration of PM_{10} versus time in June 2010 at Station A

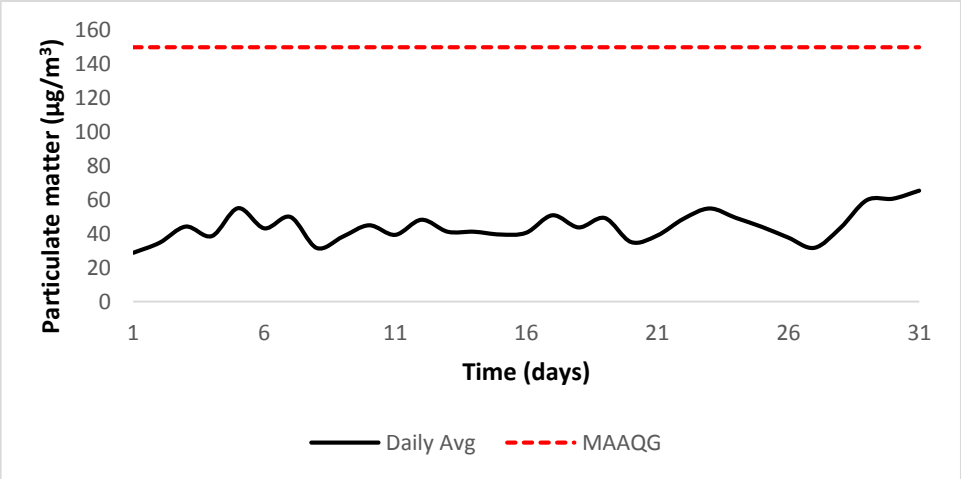


Figure A-5: Concentration of PM_{10} versus time in July 2010 at Station A

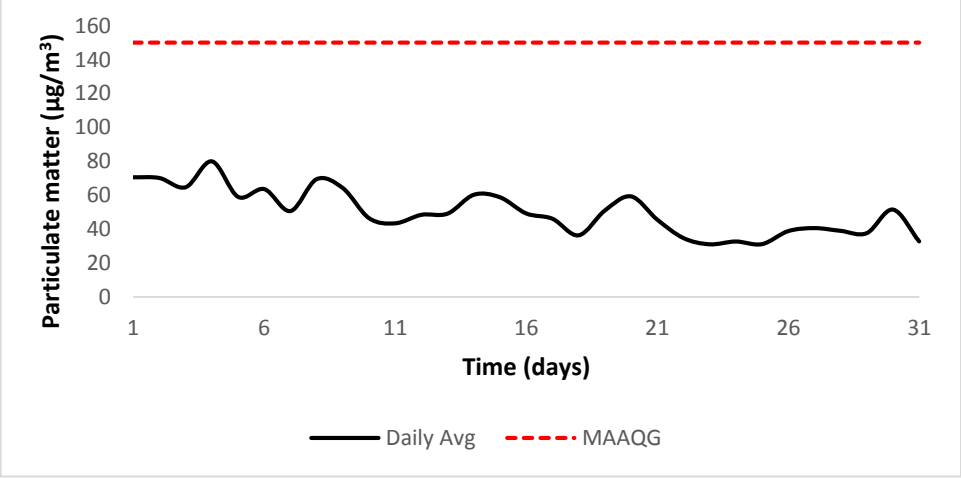


Figure A-6: Concentration of PM_{10} versus time in August 2010 at Station A

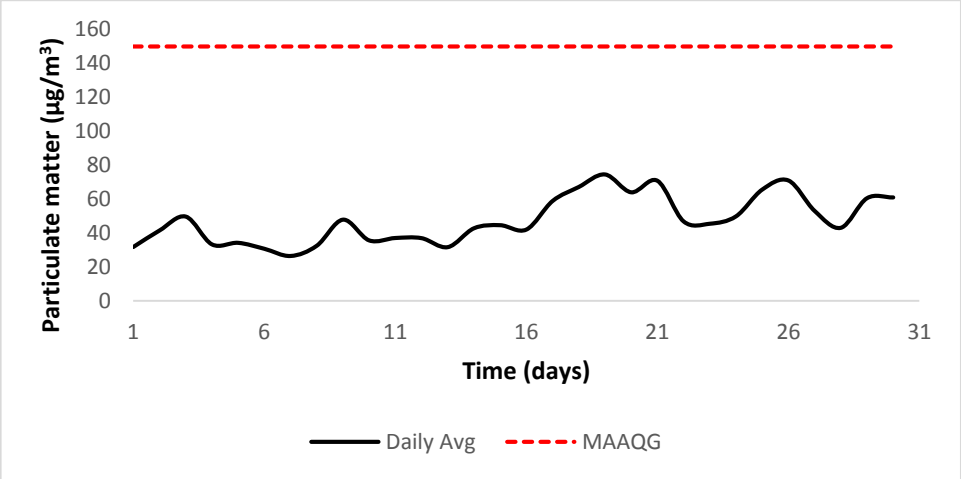


Figure A-7: Concentration of PM_{10} versus time in September 2010 at Station A

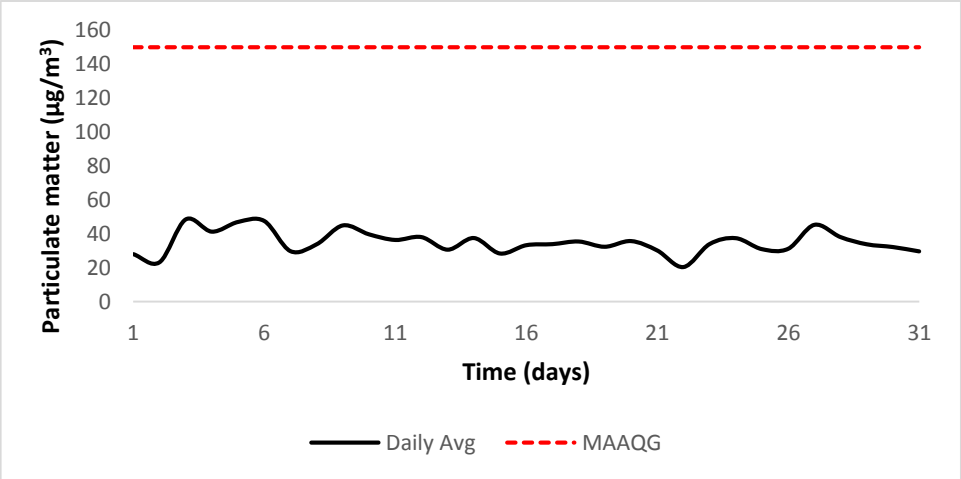


Figure A-8: Concentration of PM_{10} versus time in October 2010 at Station A

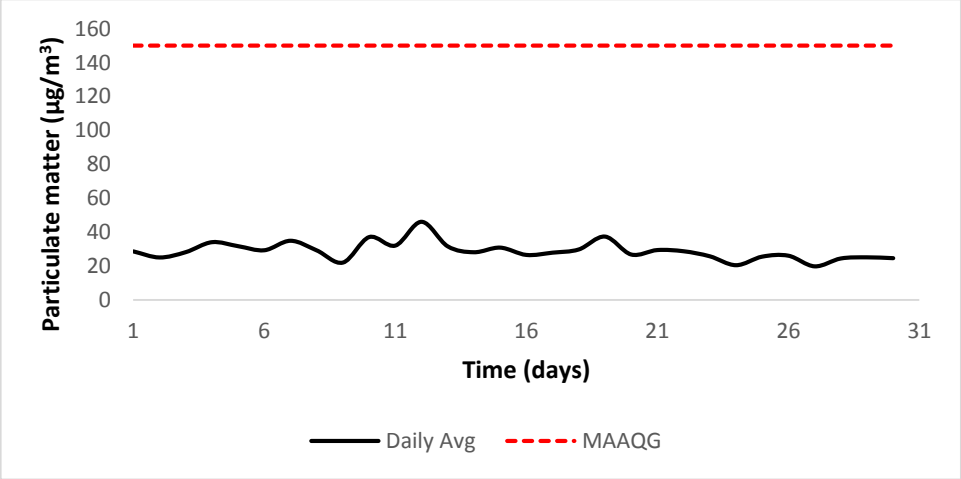


Figure A-9: Concentration of PM_{10} versus time in November 2010 at Station A

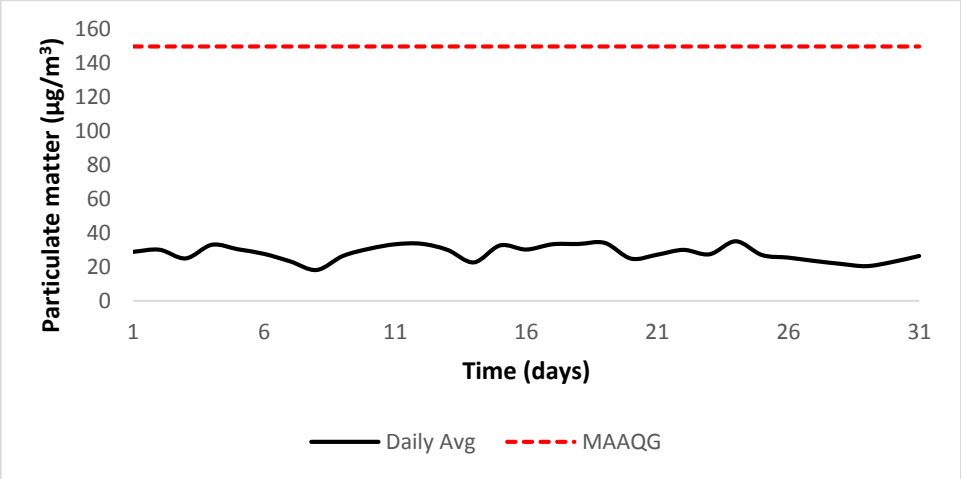


Figure A-10: Concentration of PM_{10} versus time in December 2010 at Station B

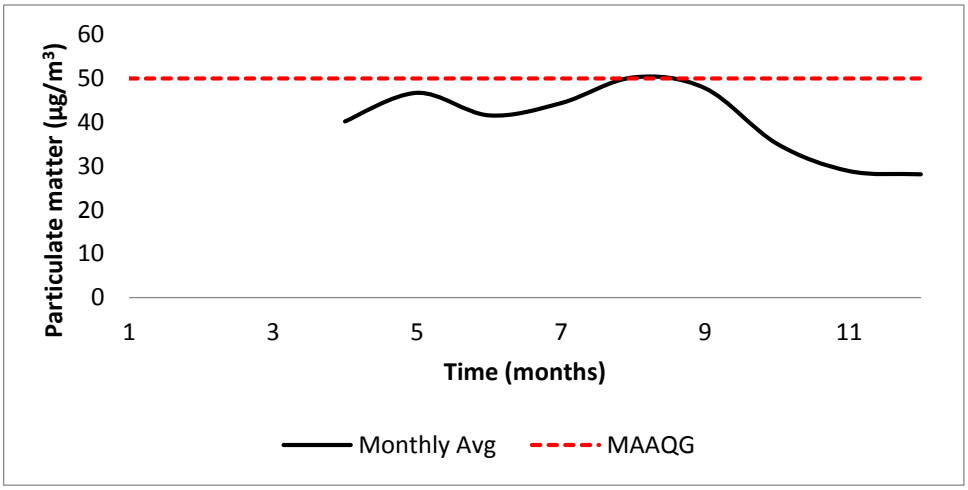


Figure A-11: Concentration of PM_{10} versus time in Year 2010 at Station A

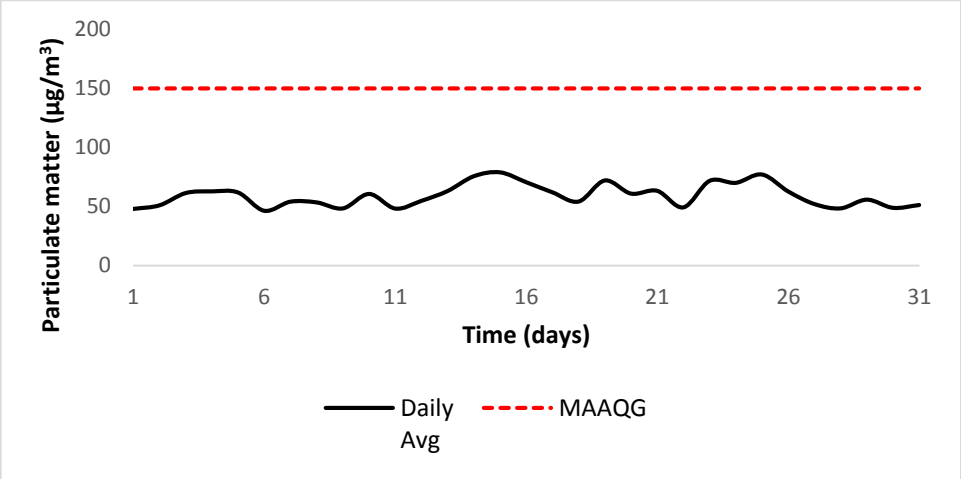


Figure A-12: Concentration of PM_{10} versus time in January 2010 at Station A

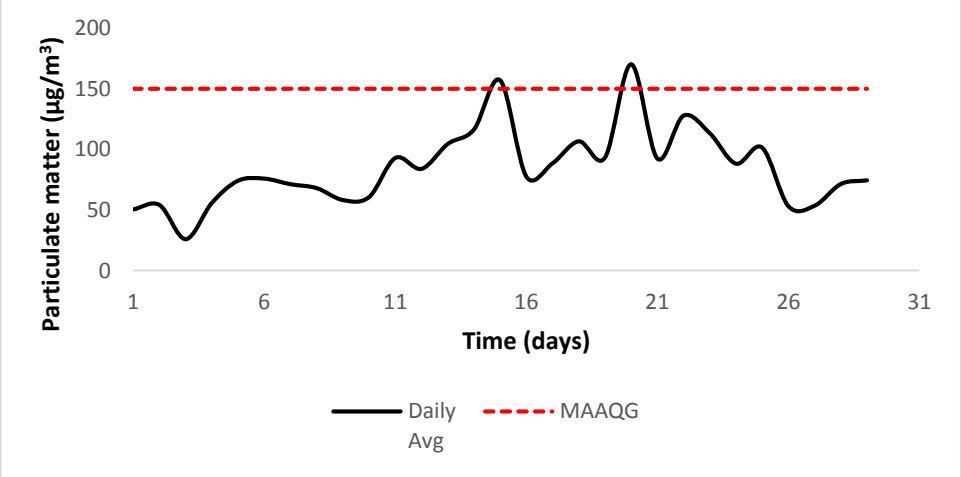


Figure A-13: Concentration of PM_{10} versus time in February 2010 at Station B

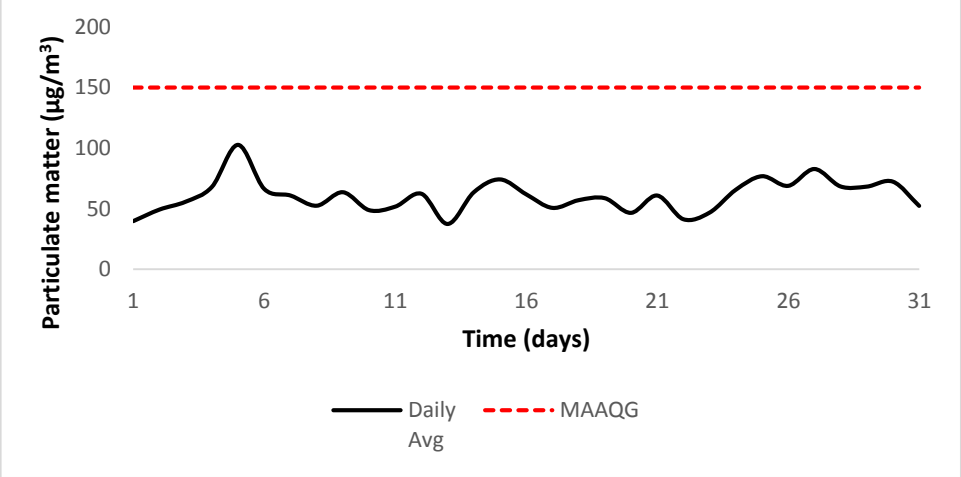


Figure A-14: Concentration of PM_{10} versus time in March 2010 at Station B

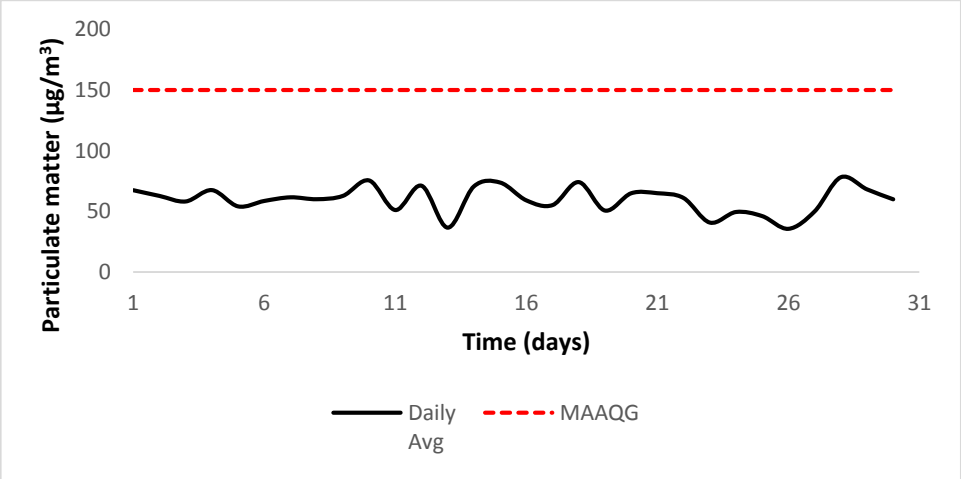


Figure A-15: Concentration of PM_{10} versus time in April 2010 at Station B

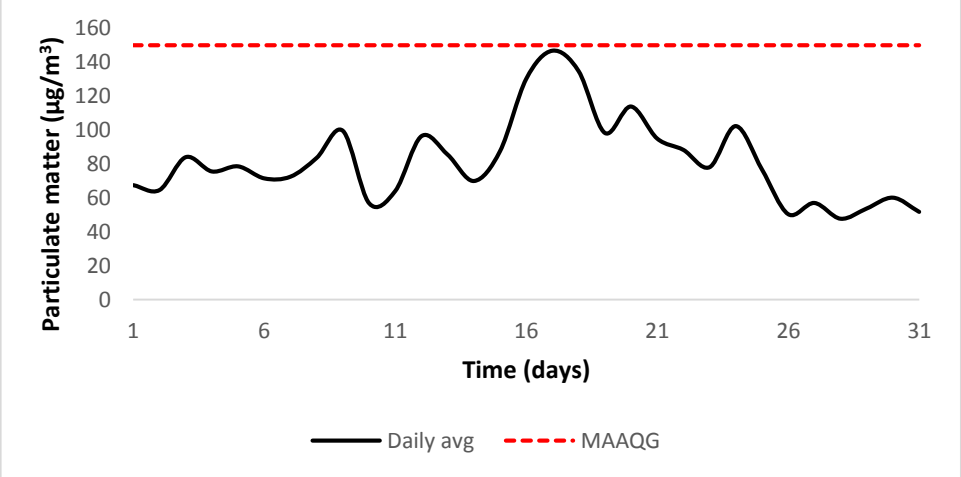


Figure A-16: Concentration of PM_{10} versus time in May 2010 at Station B

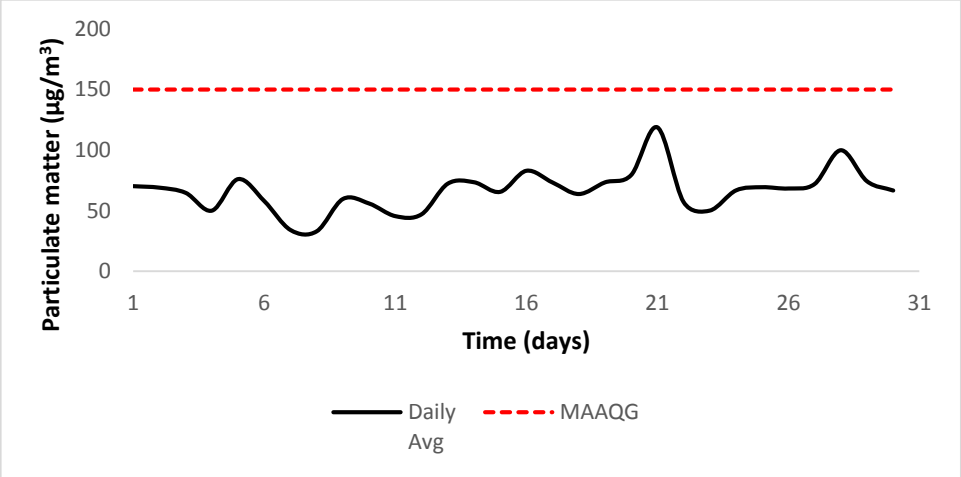


Figure A-17: Concentration of PM_{10} versus time in June 2010 at Station B

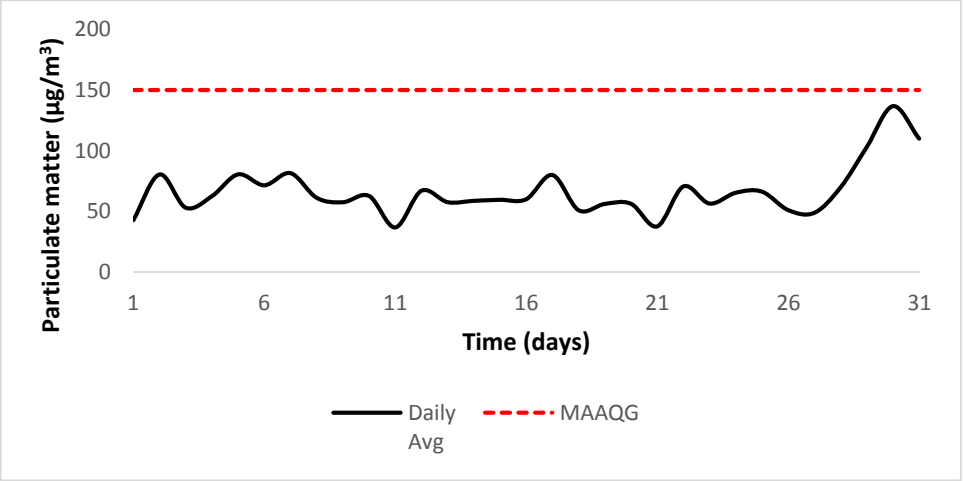


Figure A-18: Concentration of PM_{10} versus time in June 2010 at Station B

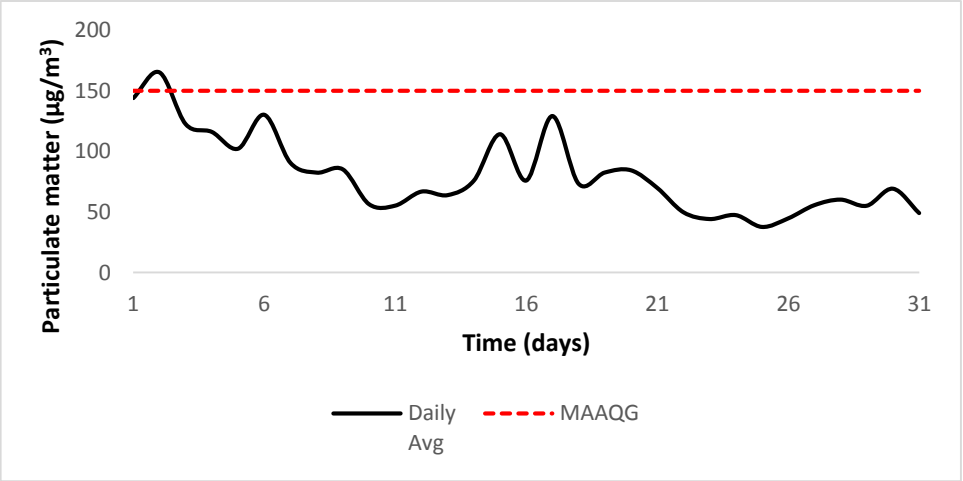


Figure A-19: Concentration of PM_{10} versus time in July 2010 at Station B

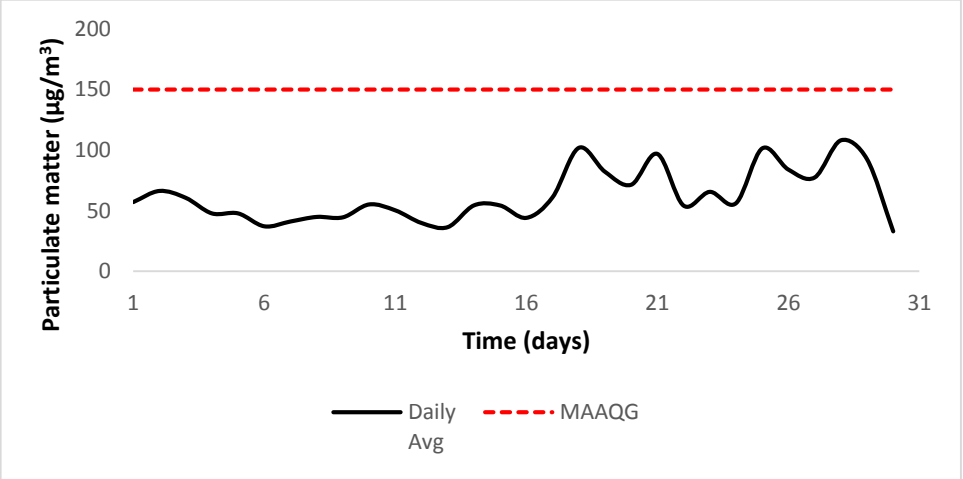


Figure A-20: Concentration of PM_{10} versus time in August 2010 at Station B

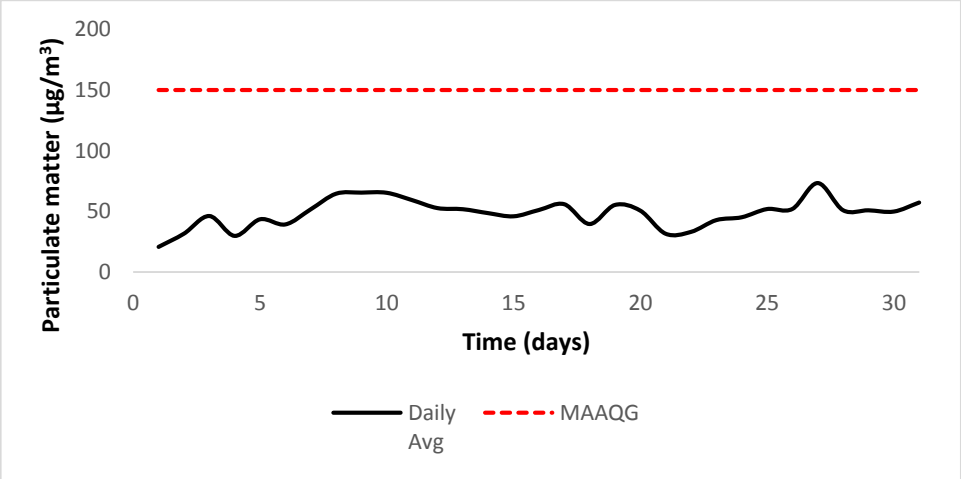


Figure A-21: Concentration of PM_{10} versus time in September 2010 at Station B

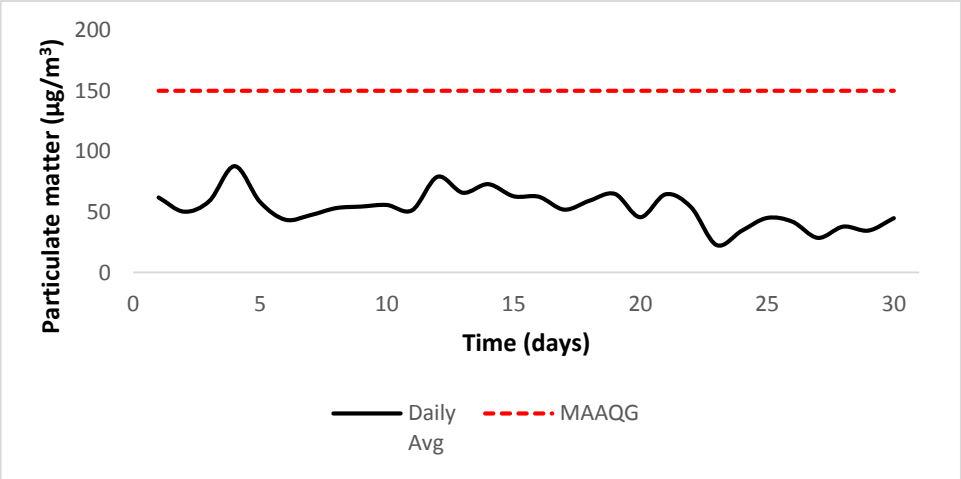


Figure A-22: Concentration of PM_{10} versus time in November 2010 at Station B

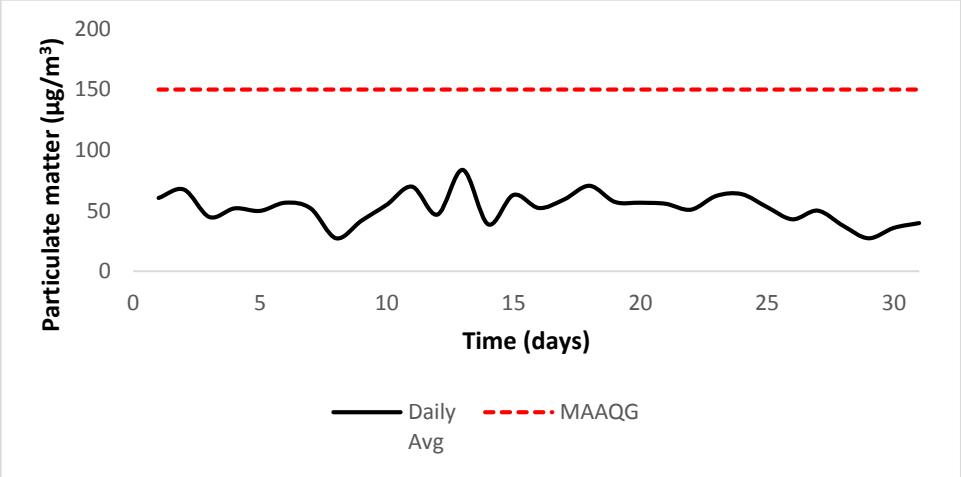


Figure A-23: Concentration of PM_{10} versus time in December 2010 at Station B

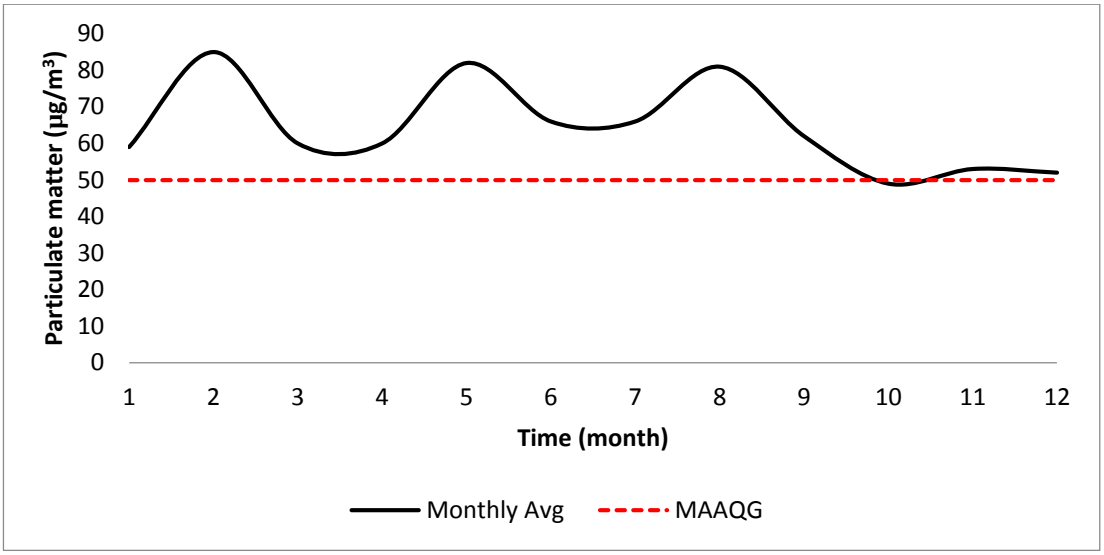


Figure A-24: Concentration of PM_{10} versus time in Year 2010 at Station B

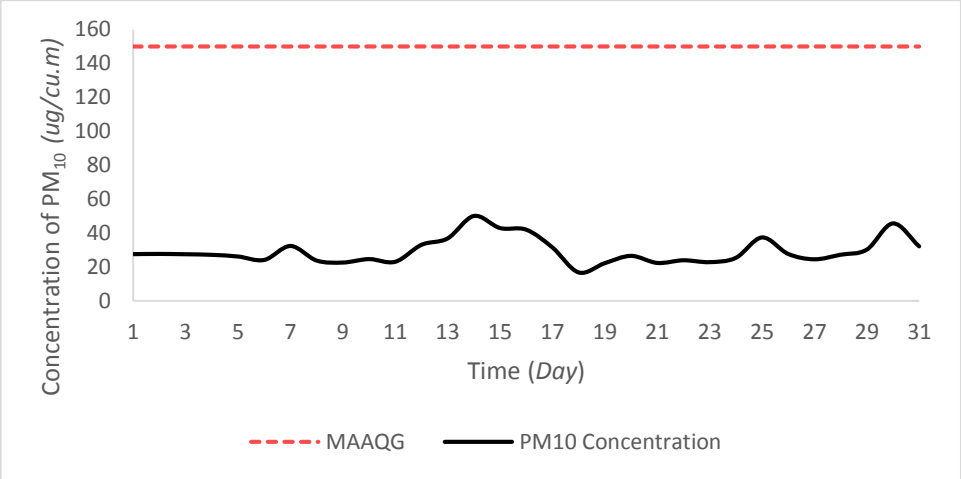


Figure A-25: Concentration of PM_{10} versus time in January 2008 at Station CA0007

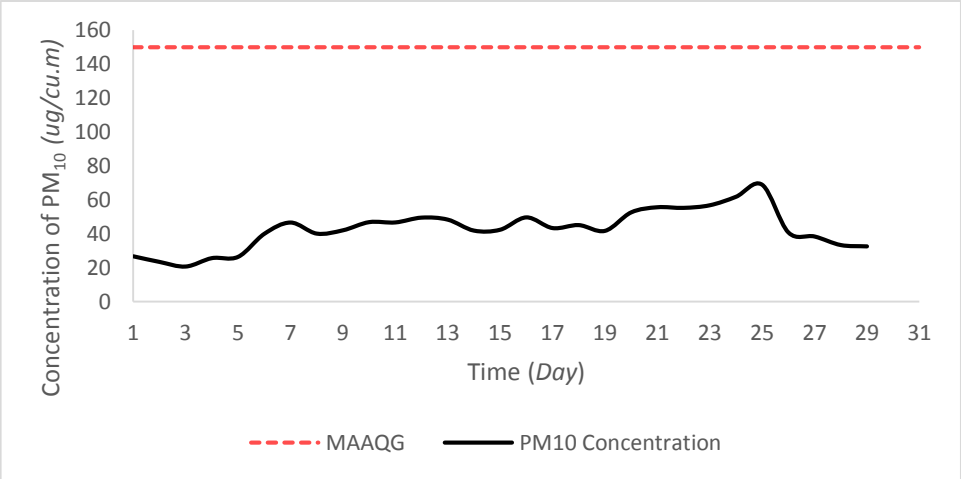


Figure A-26: Concentration of PM_{10} versus time in February 2008 at Station CA0007

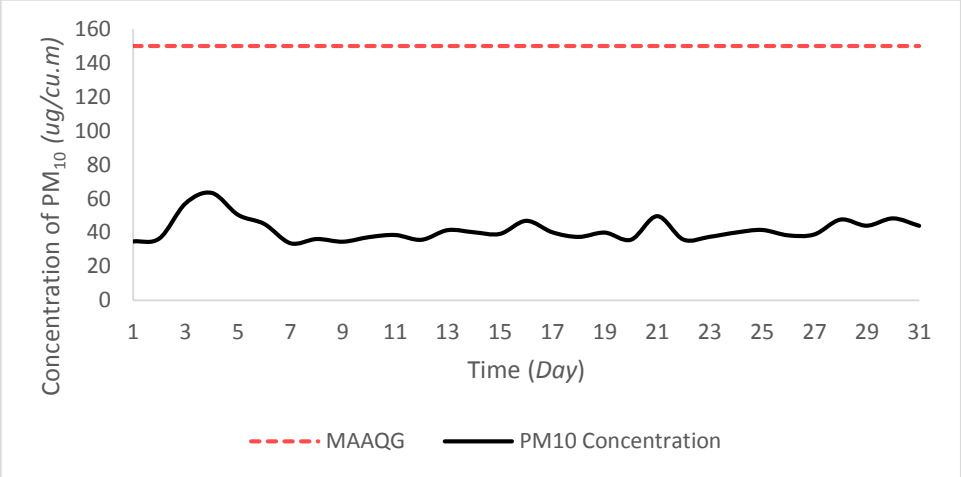


Figure A-27: Concentration of PM_{10} versus time in March 2008 at Station CA0007

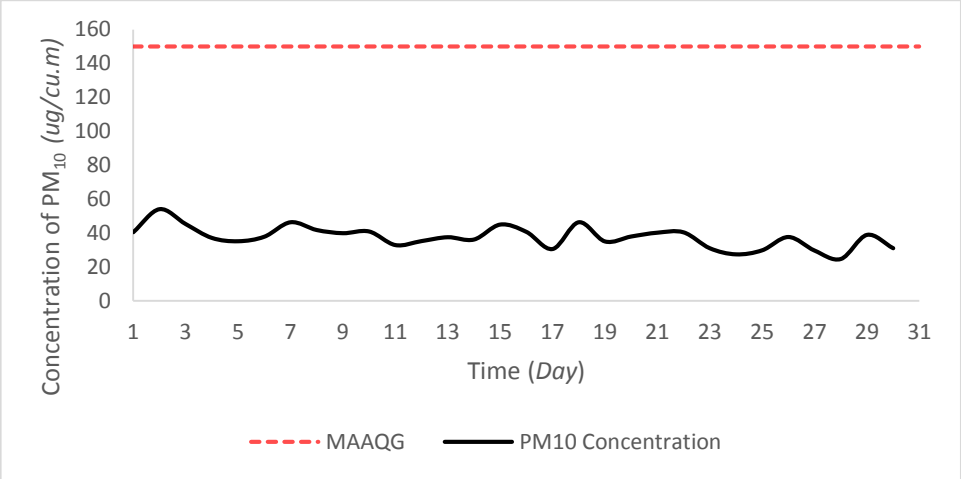


Figure A-28: Concentration of PM_{10} versus time in April 2008 at Station CA0007

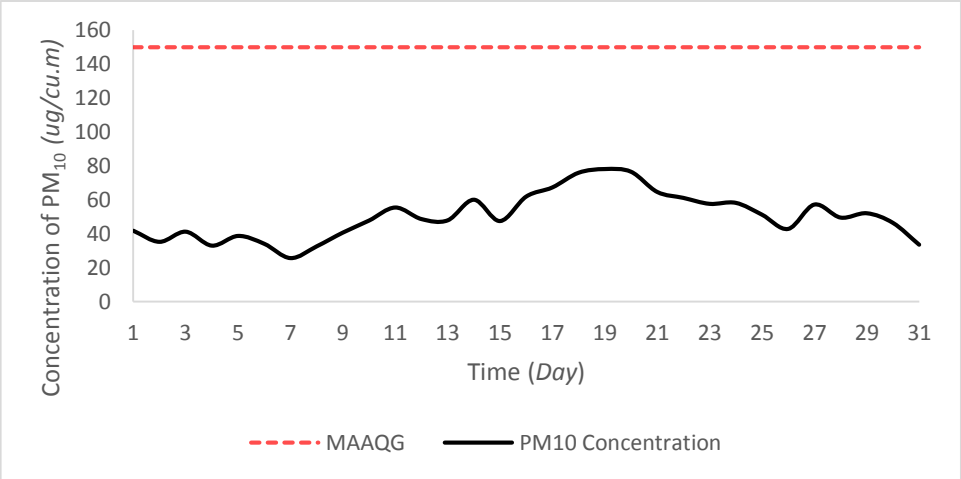


Figure A-29: Concentration of PM_{10} versus time in May 2008 at Station CA0007

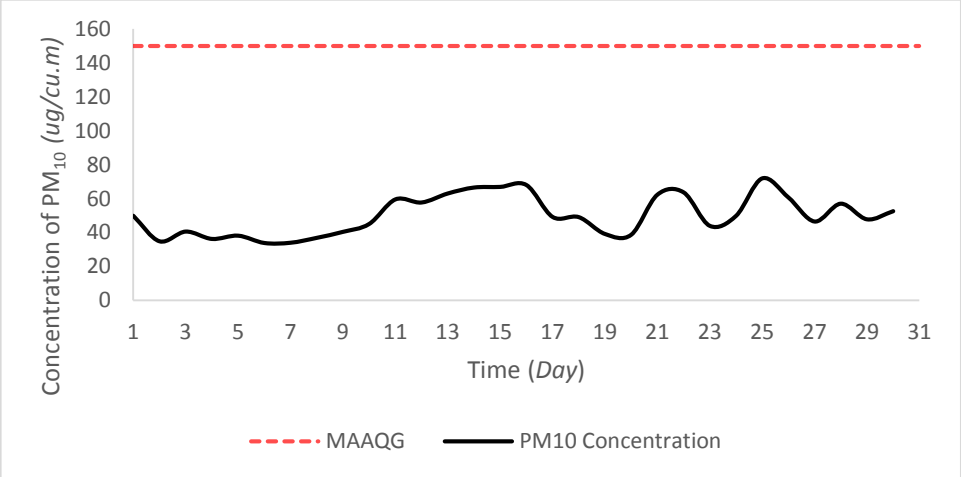


Figure A-30: Concentration of PM_{10} versus time in June 2008 at Station CA0007

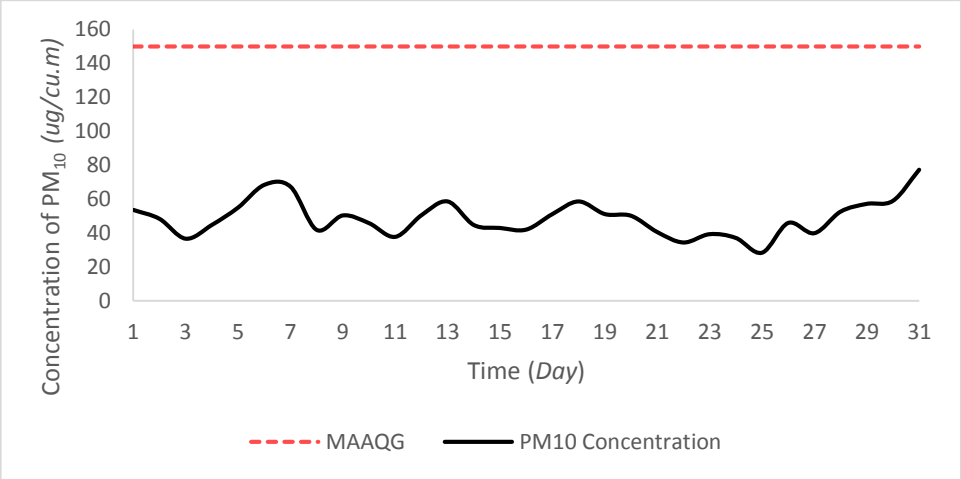


Figure A-31: Concentration of PM_{10} versus time in July 2008 at Station CA0007

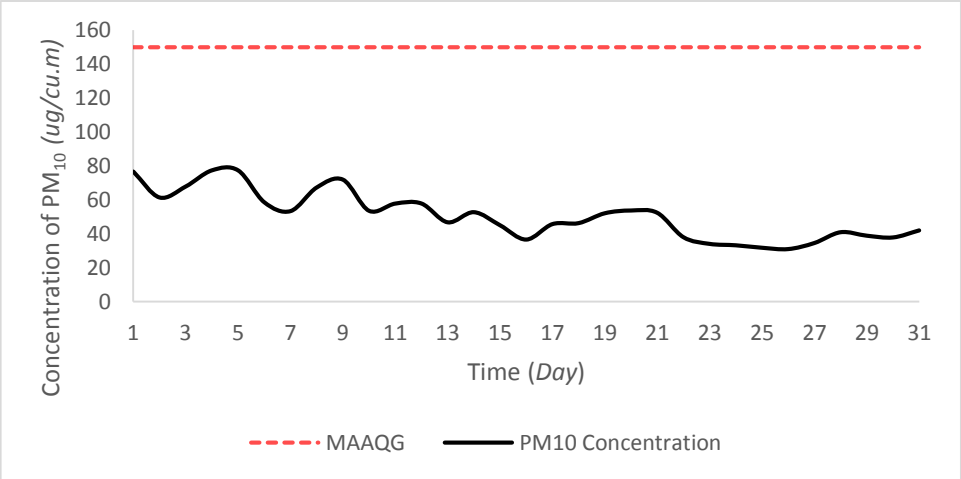


Figure A-32: Concentration of PM_{10} versus time in August 2008 at Station CA0007

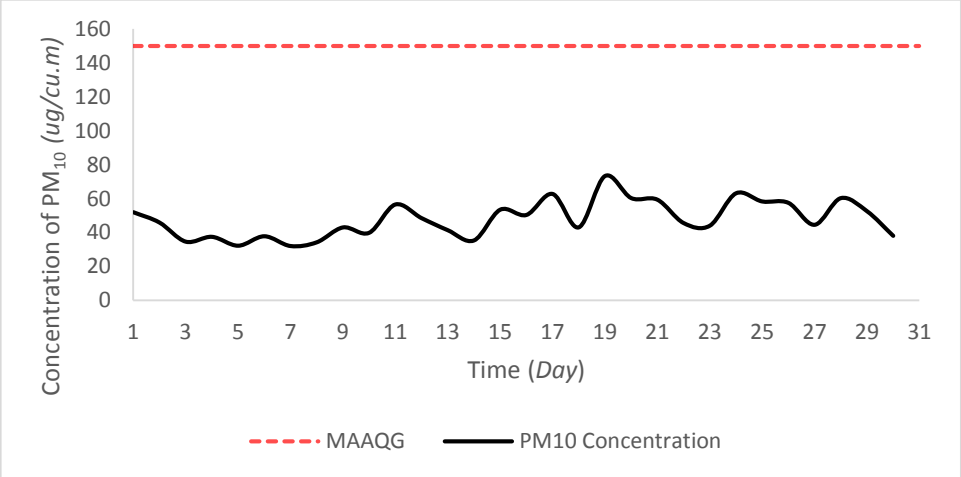


Figure A-33: Concentration of PM_{10} versus time in September 2008 at Station CA0007

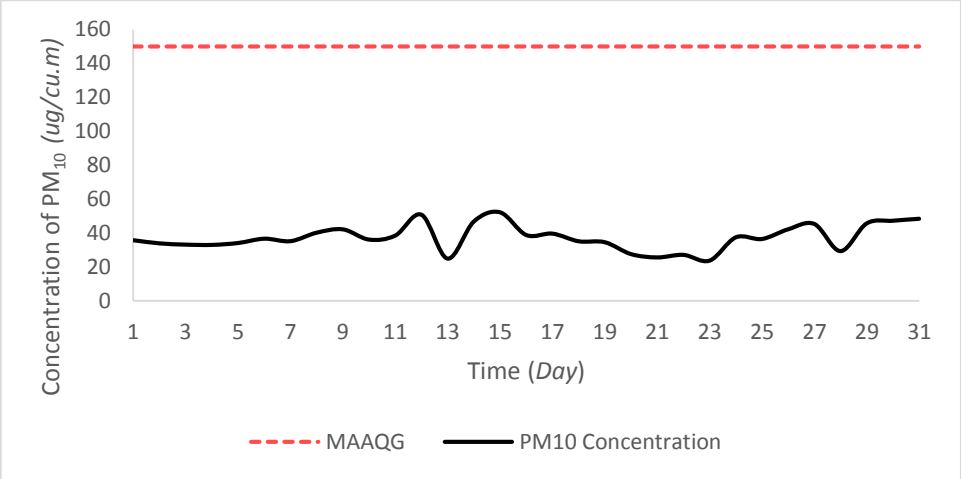


Figure A-34: Concentration of PM_{10} versus time in October 2008 at Station CA0007

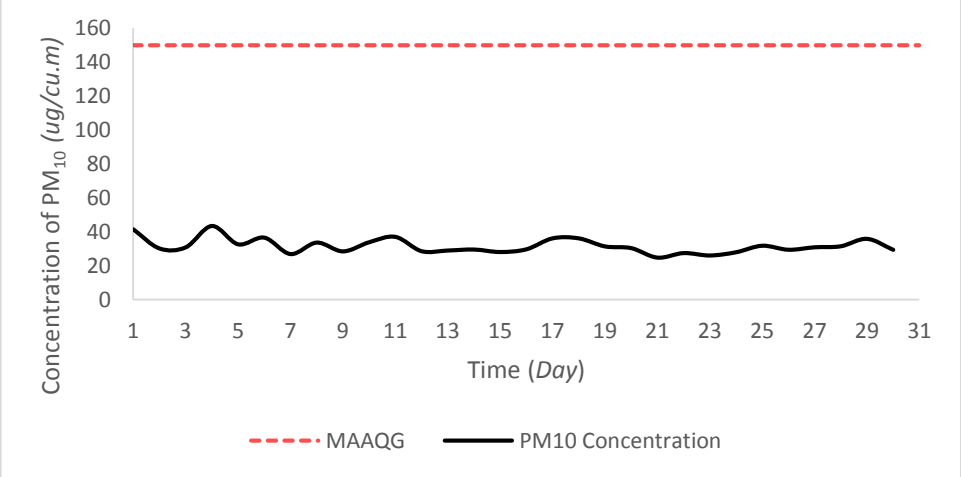


Figure A-35: Concentration of PM_{10} versus time in November 2008 at Station CA0007

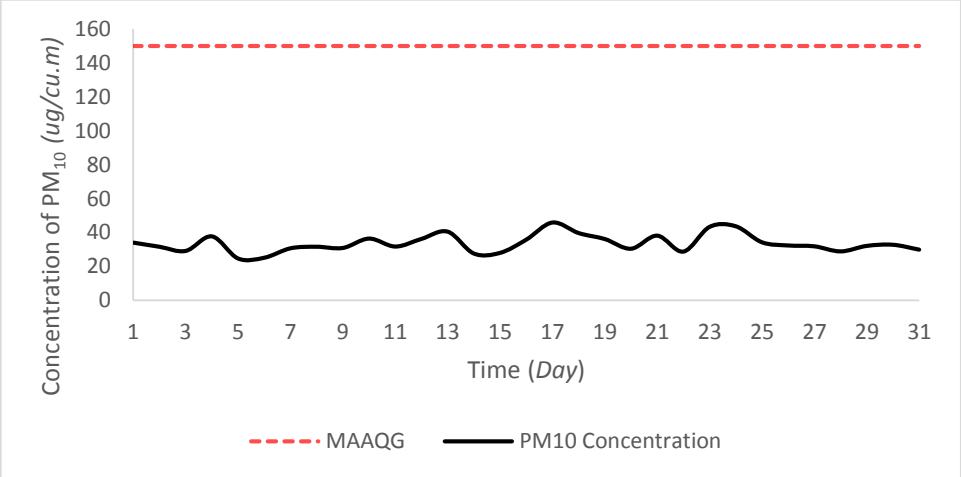


Figure A-36: Concentration of PM_{10} versus time in December 2008 at Station CA0007

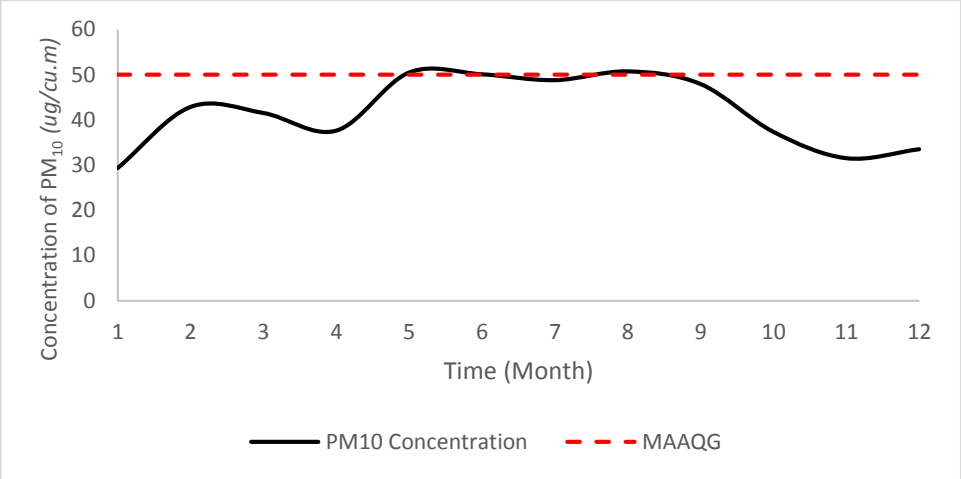


Figure A-37: Concentration of PM_{10} versus time in Year 2008 at Station CA0007

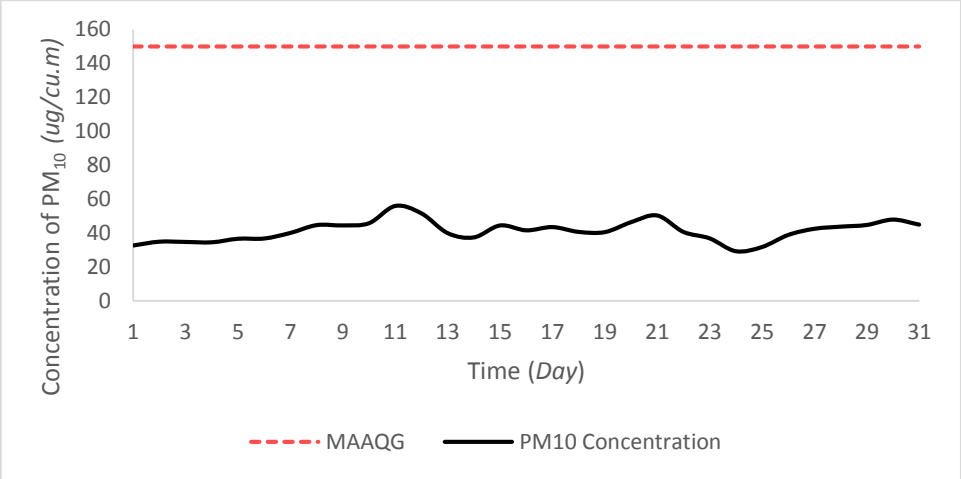


Figure A-38: Concentration of PM_{10} versus time in January 2009 at Station CA0007

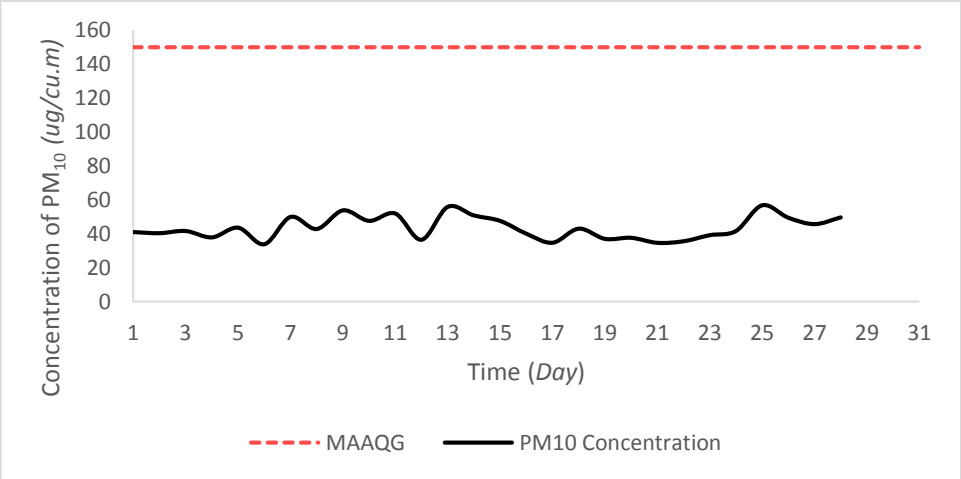


Figure A-39: Concentration of PM_{10} versus time in February 2009 at Station CA0007

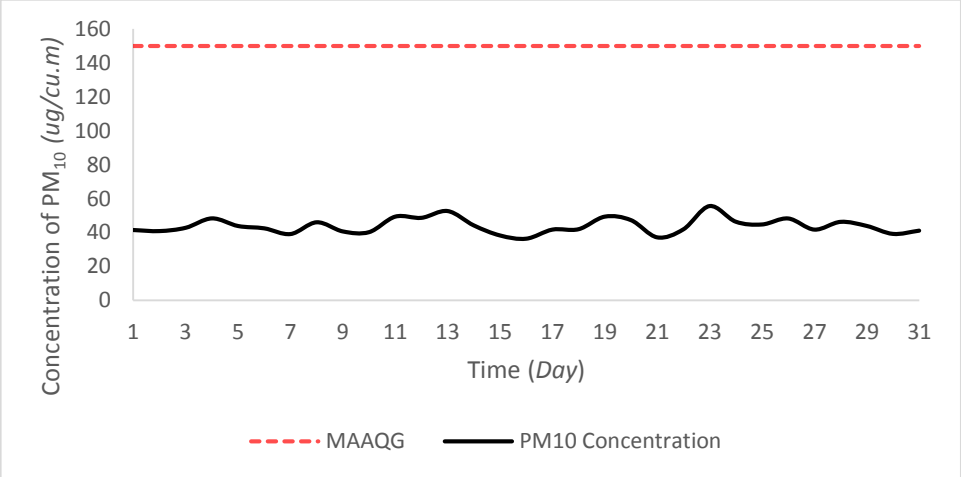


Figure A-40: Concentration of PM_{10} versus time in March 2009 at Station CA0007

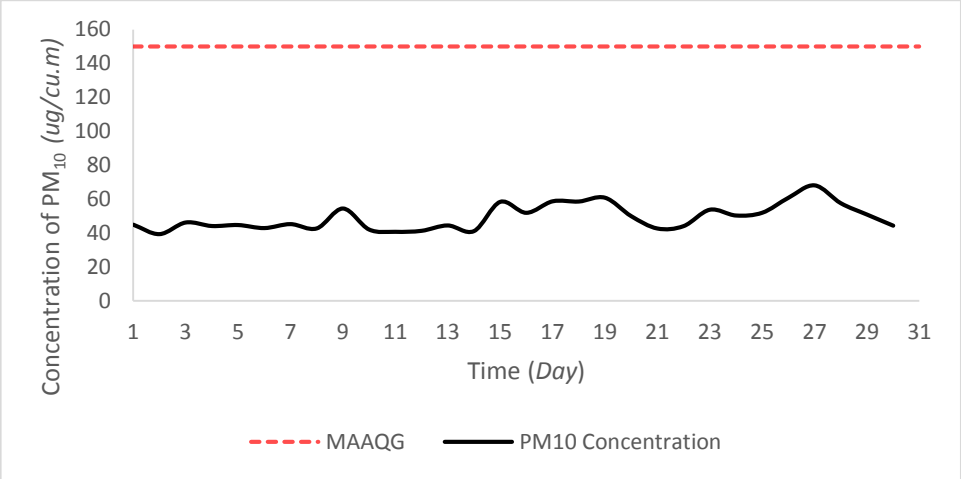


Figure A-41: Concentration of PM_{10} versus time in April 2009 at Station CA0007

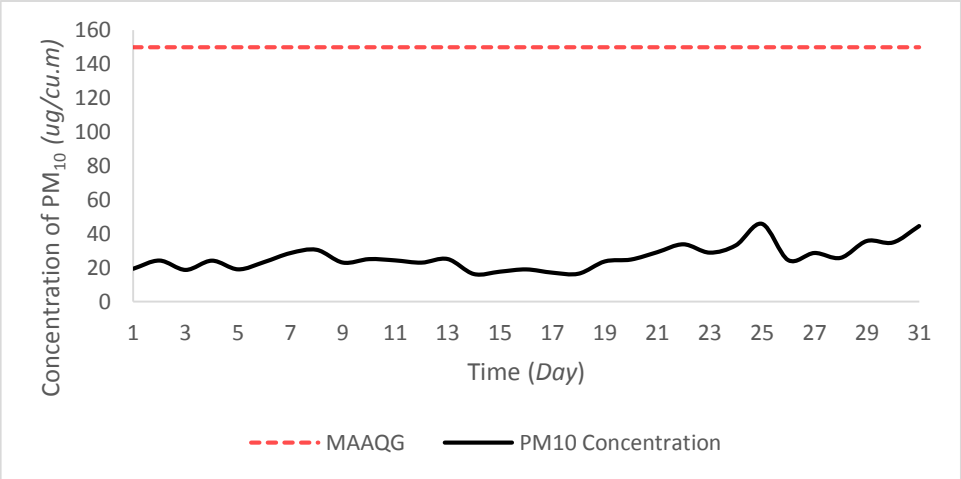


Figure A-42: Concentration of PM_{10} versus time in May 2009 at Station CA0007

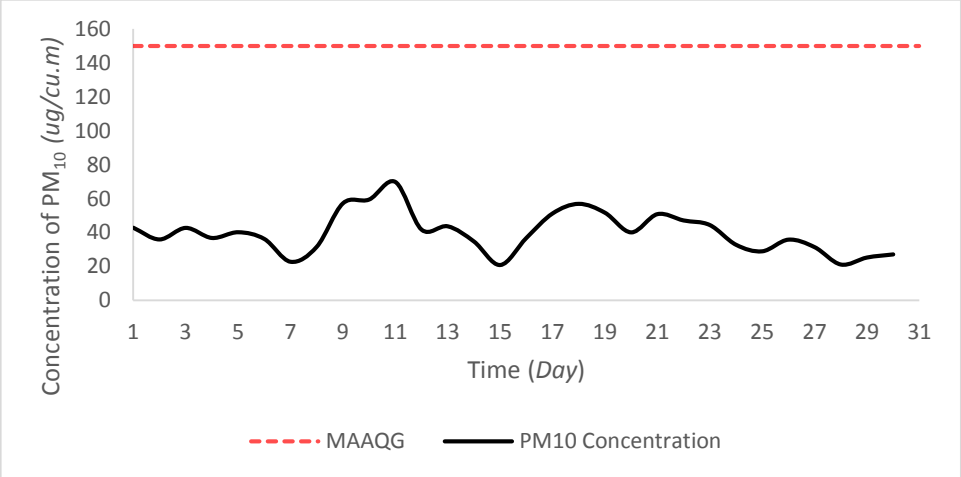


Figure A-43: Concentration of PM_{10} versus time in June 2009 at Station CA0007

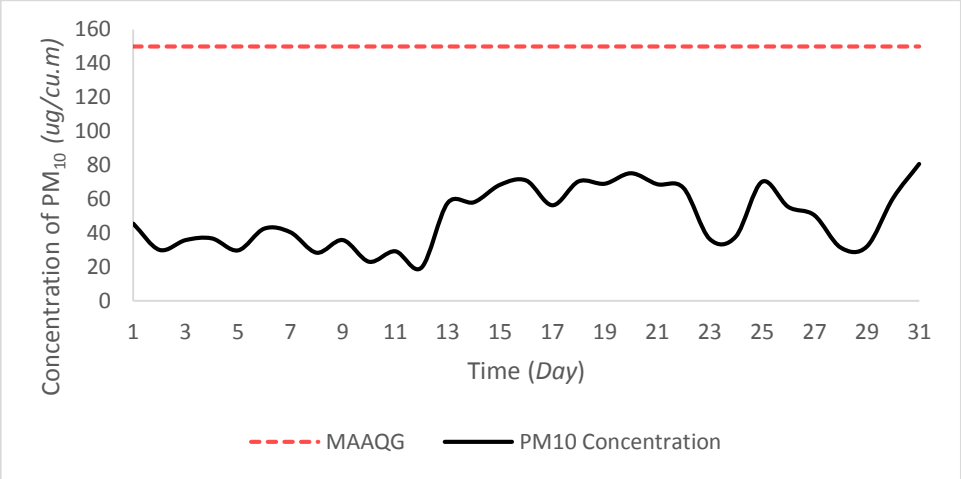


Figure A-44: Concentration of PM_{10} versus time in July 2009 at Station CA0007

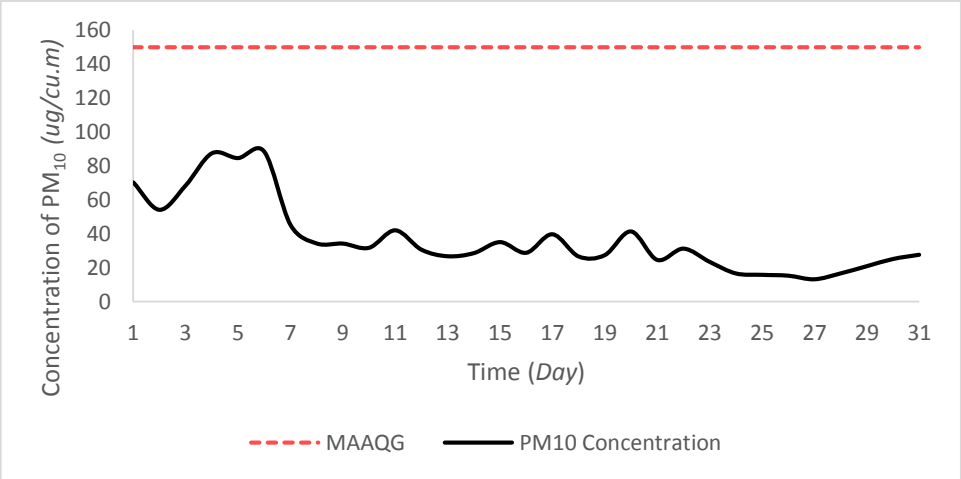


Figure A-46: Concentration of PM_{10} versus time in August 2009 at Station CA0007

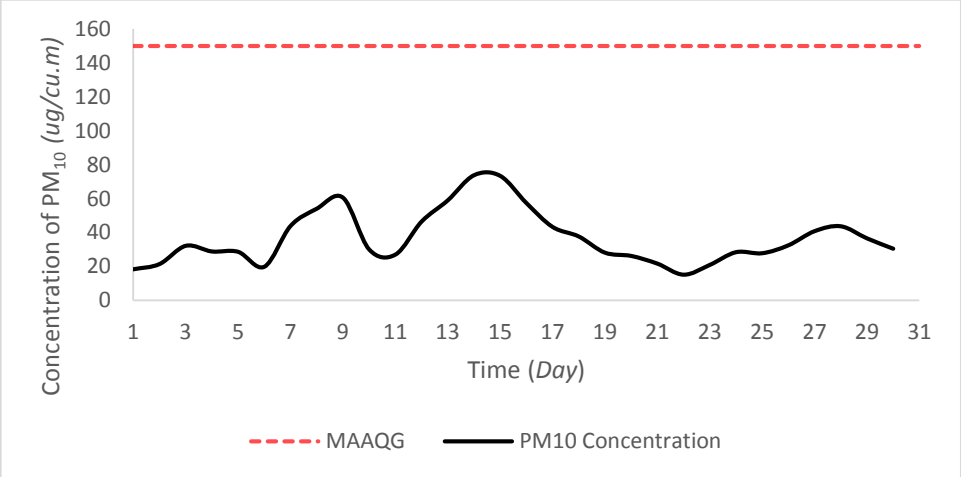


Figure A-47: Concentration of PM_{10} versus time in September 2009 at Station CA0007

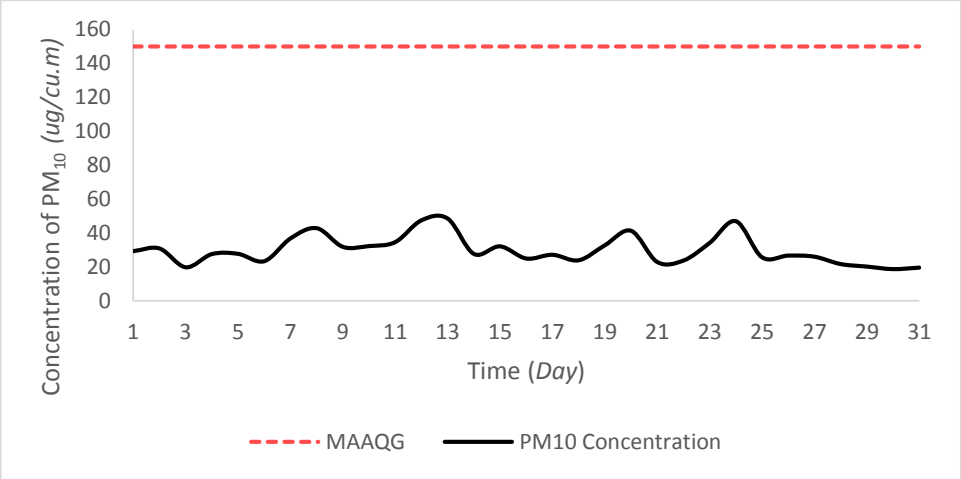


Figure A-48: Concentration of PM_{10} versus time in October 2009 at Station CA0007

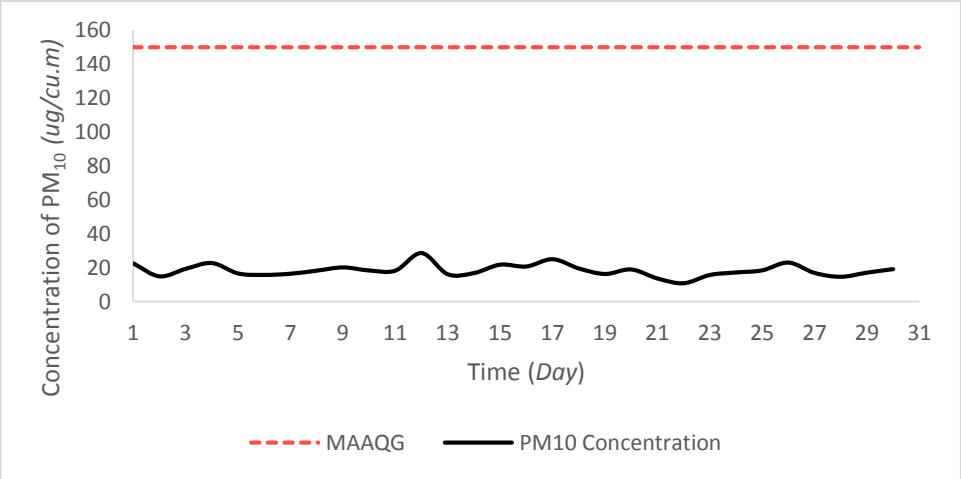


Figure A-49: Concentration of PM_{10} versus time in November 2009 at Station CA0007

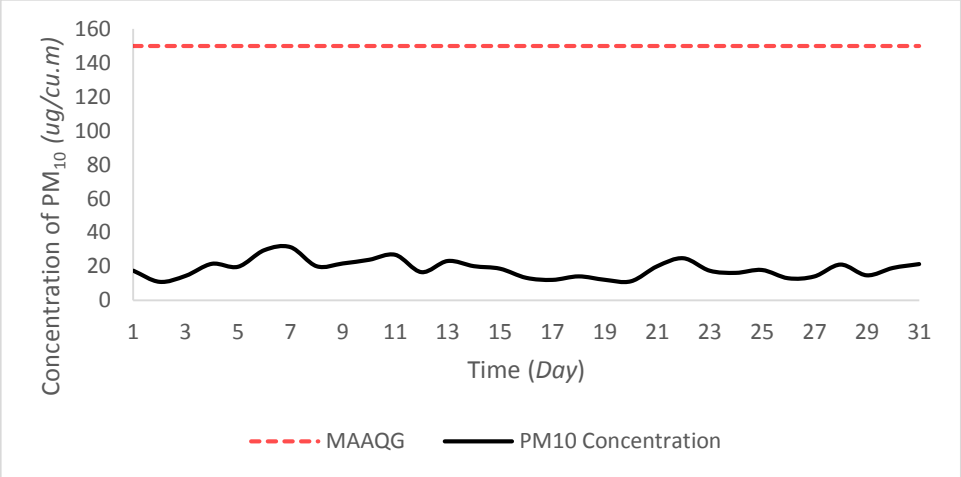


Figure A-50: Concentration of PM_{10} versus time in December 2009 at Station CA0007

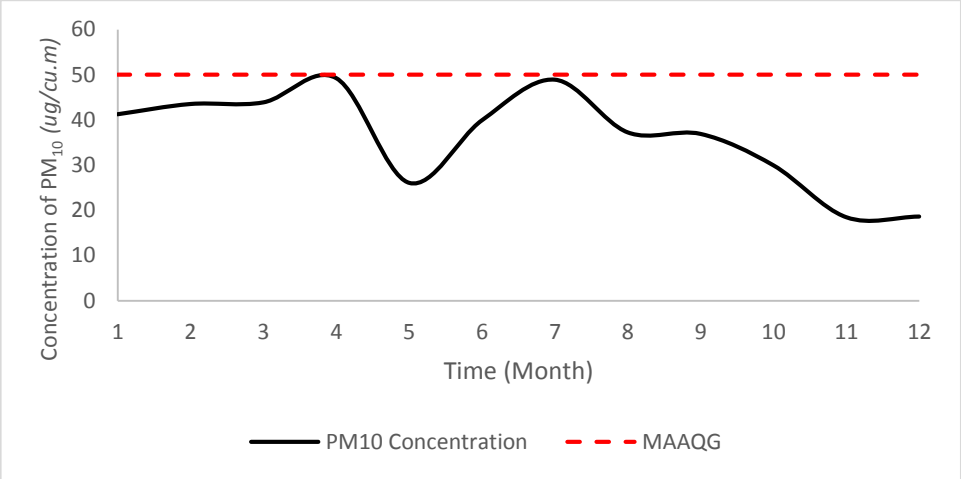


Figure A-51: Concentration of PM_{10} versus time in Year 2009 at Station CA0007

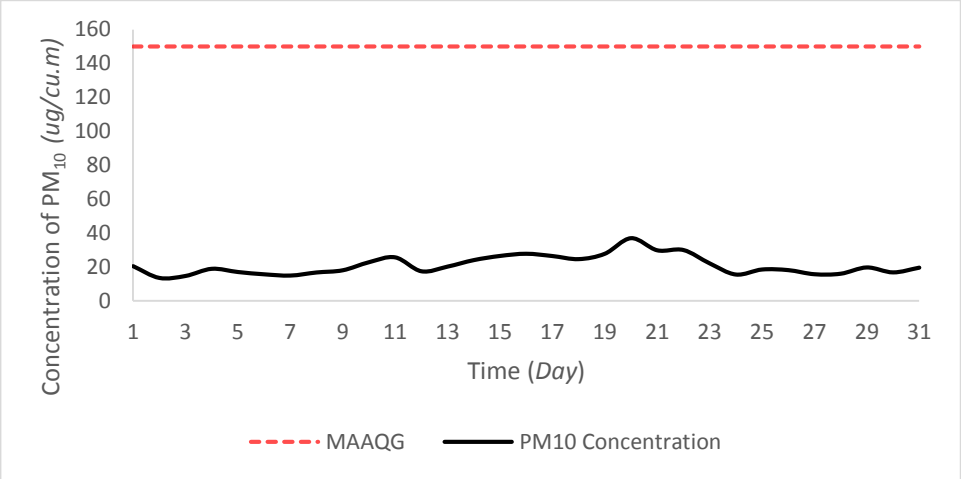


Figure A-52: Concentration of PM_{10} versus time in January 2010 at Station CA0007

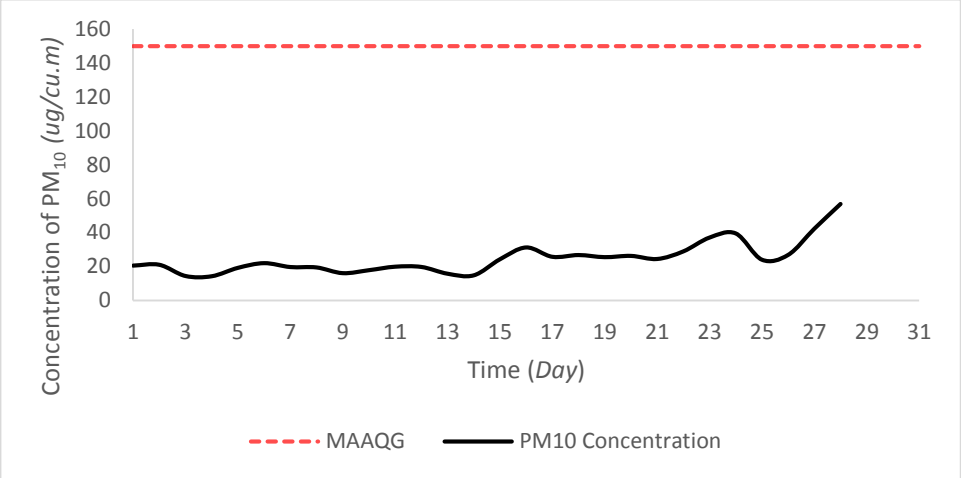


Figure A-53: Concentration of PM_{10} versus time in February 2010 at Station CA0007

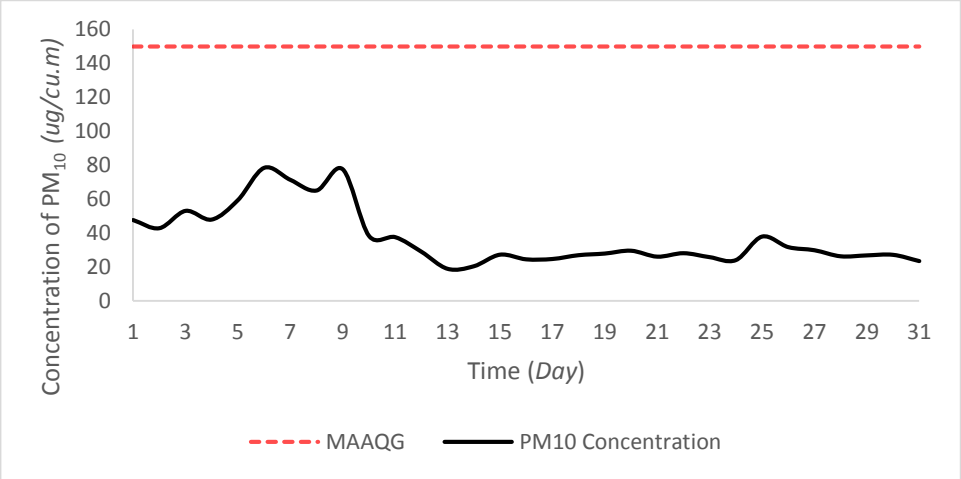


Figure A-54: Concentration of PM_{10} versus time in March 2010 at Station CA0007

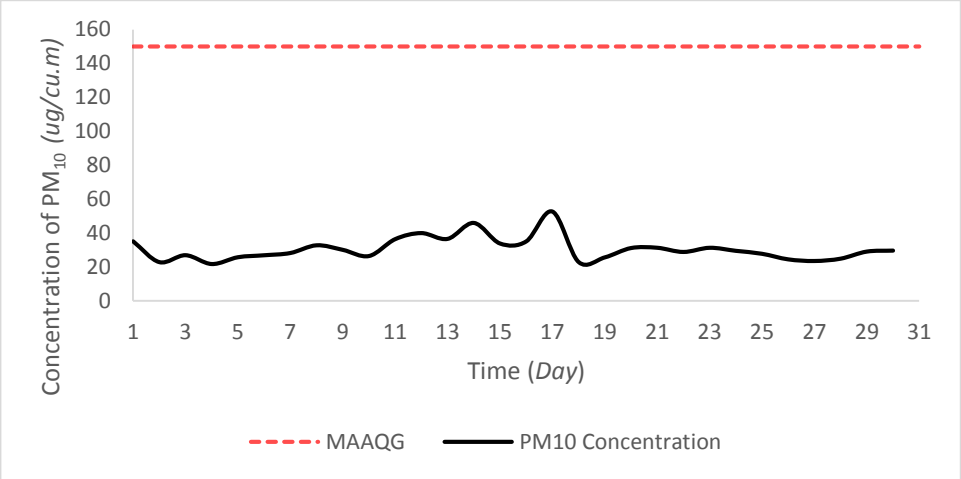


Figure A-55: Concentration of PM_{10} versus time in April 2010 at Station CA0007

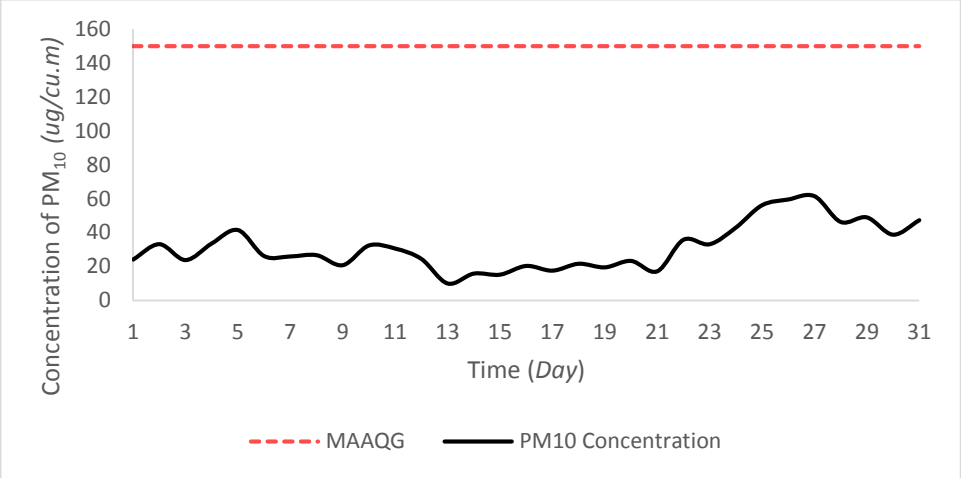


Figure A-56: Concentration of PM_{10} versus time in May 2010 at Station CA0007

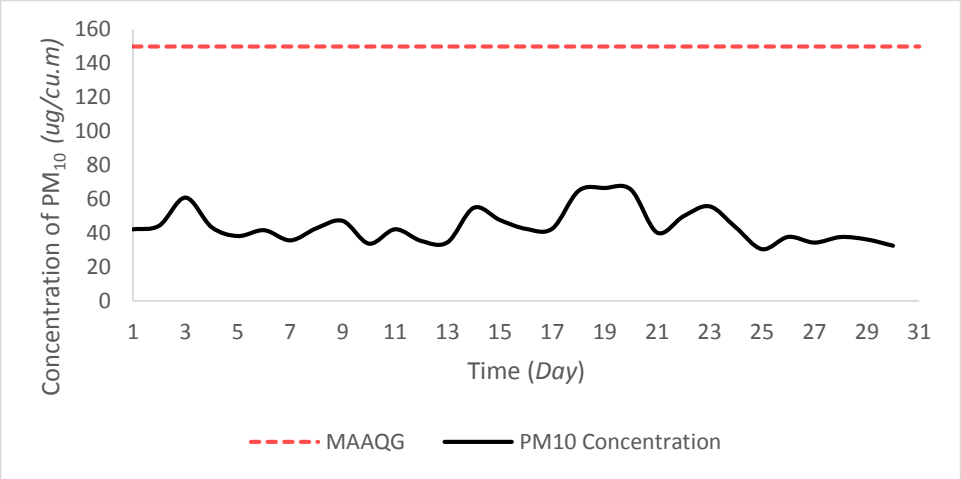


Figure A-57: Concentration of PM_{10} versus time in June 2010 at Station CA0007

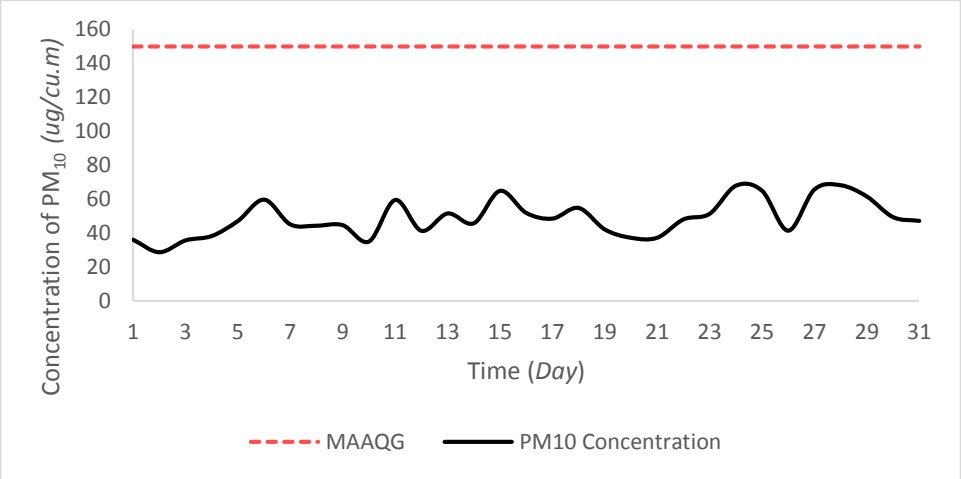


Figure A-58: Concentration of PM_{10} versus time in July 2010 at Station CA0007

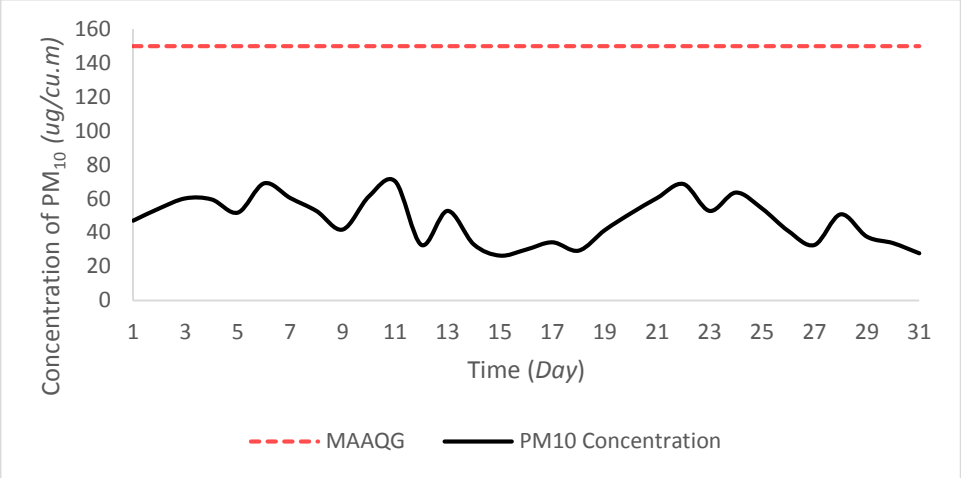


Figure A-59: Concentration of PM_{10} versus time in August 2010 at Station CA0007

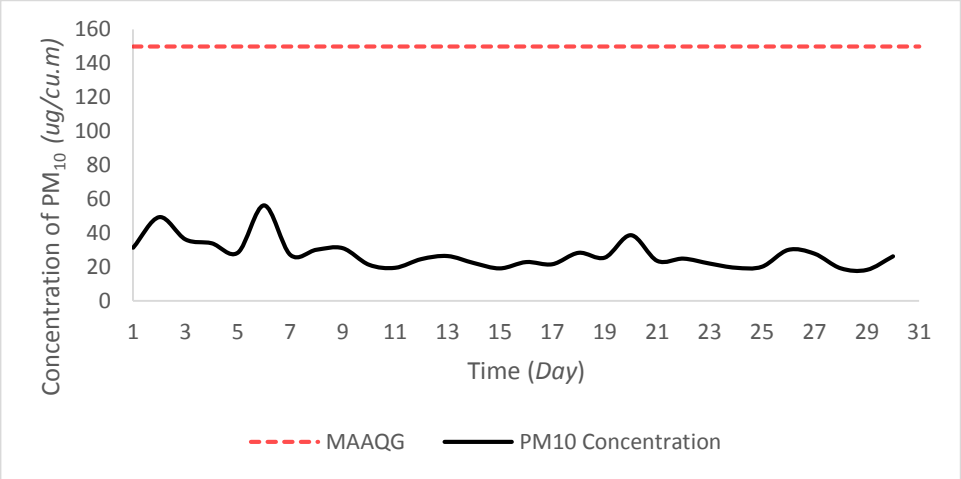


Figure A-60: Concentration of PM_{10} versus time in September 2010 at Station CA0007

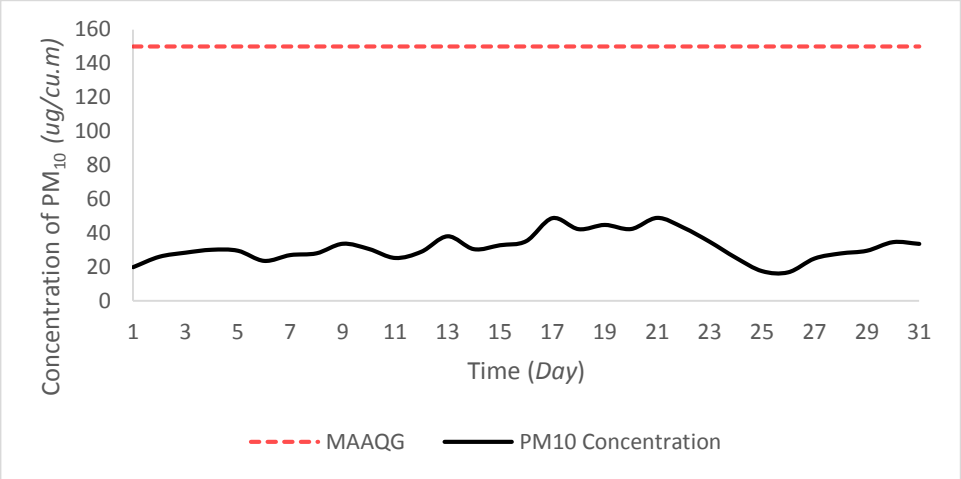


Figure A-61: Concentration of PM_{10} versus time in October 2010 at Station CA0007

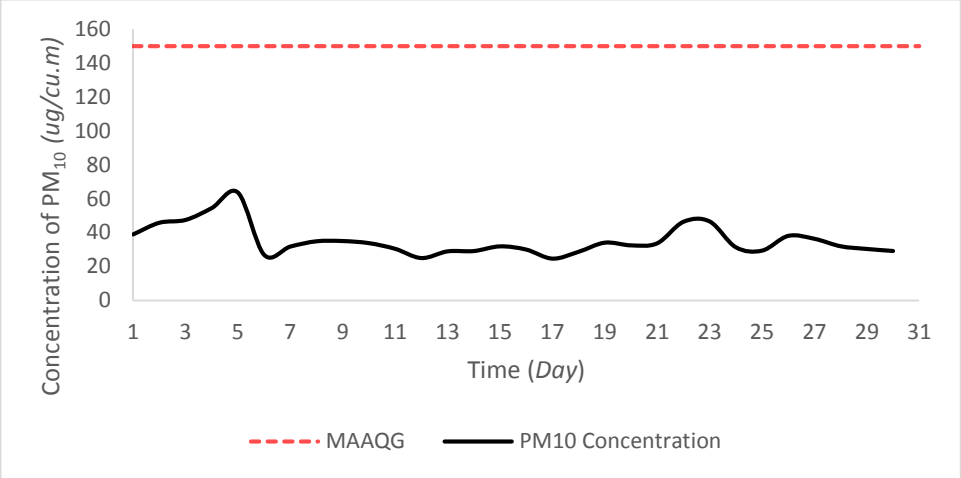


Figure A-62: Concentration of PM_{10} versus time in November 2010 at Station CA0007

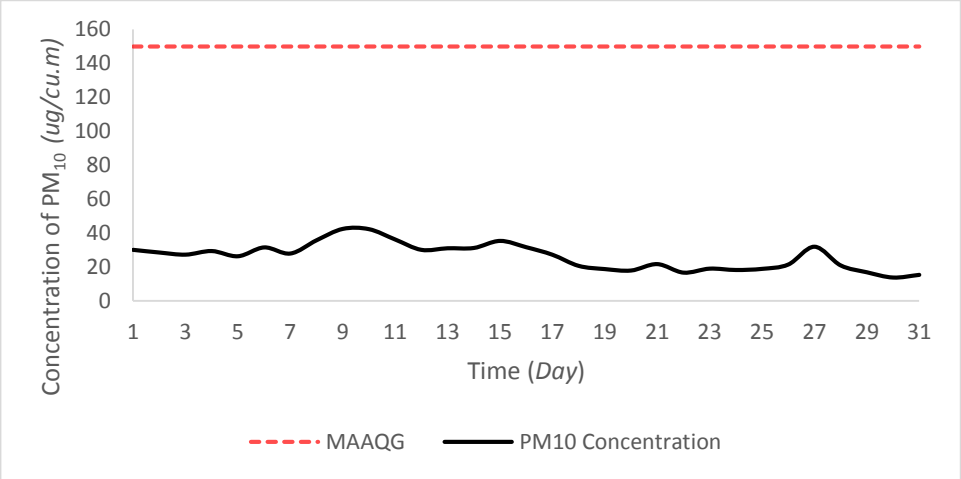


Figure A-63: Concentration of PM_{10} versus time in December 2010 at Station CA0007

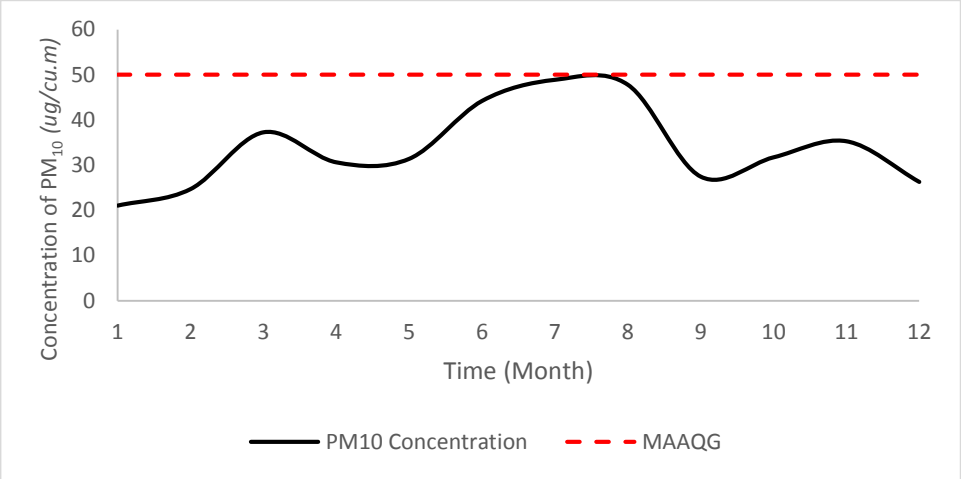


Figure A-64: Concentration of PM_{10} versus time in Year 2010 at Station CA0007

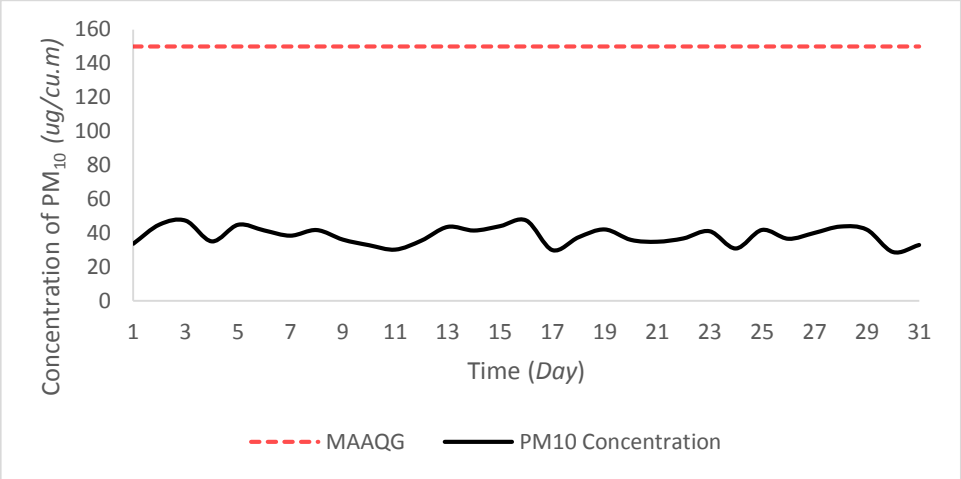


Figure A-65: Concentration of PM_{10} versus time in January 2008 at Station CA0024

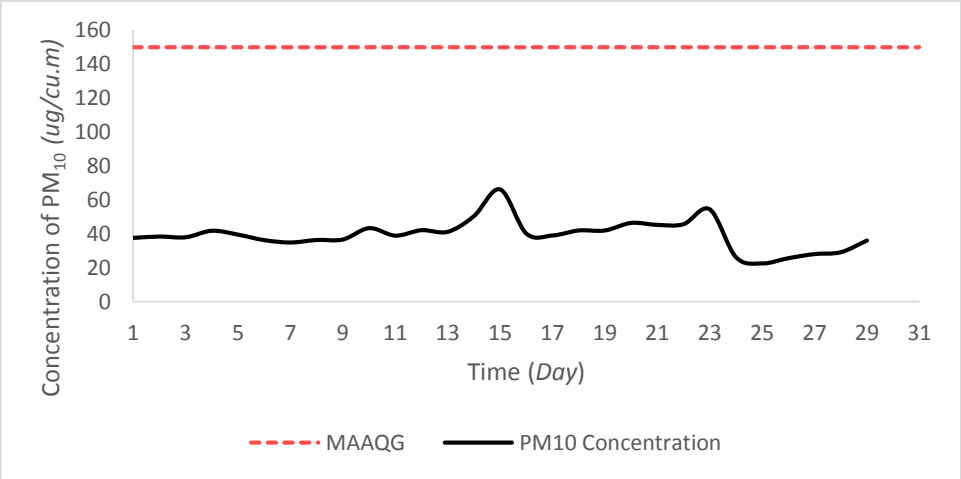


Figure A-66: Concentration of PM_{10} versus time in February 2008 at Station CA0024

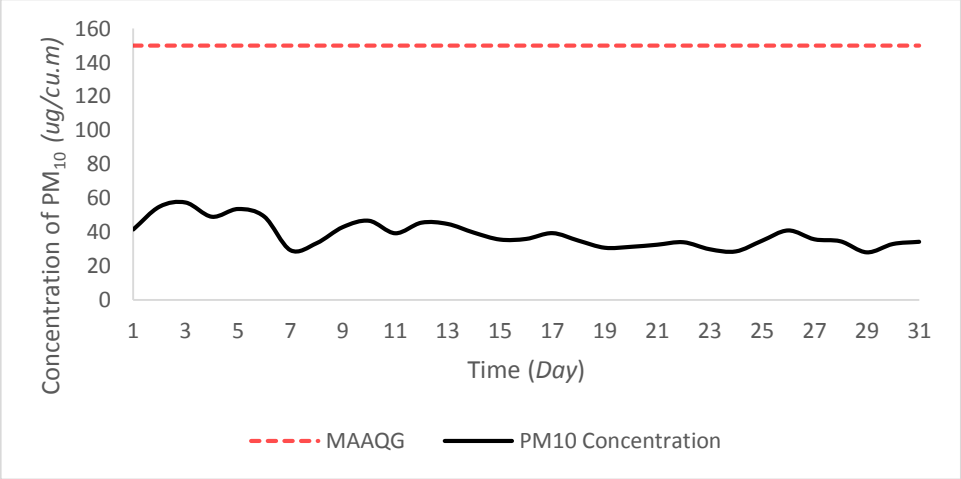


Figure A-67: Concentration of PM_{10} versus time in March 2008 at Station CA0024

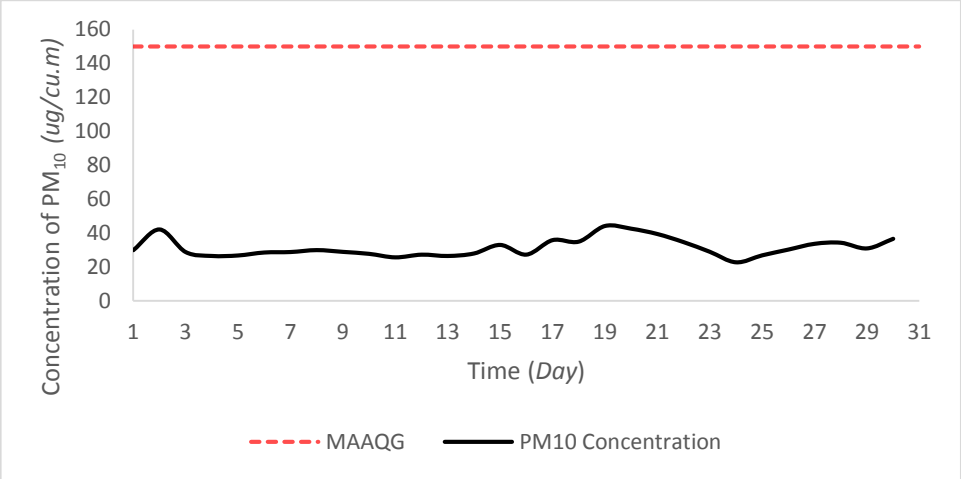


Figure A-68: Concentration of PM_{10} versus time in April 2008 at Station CA0024

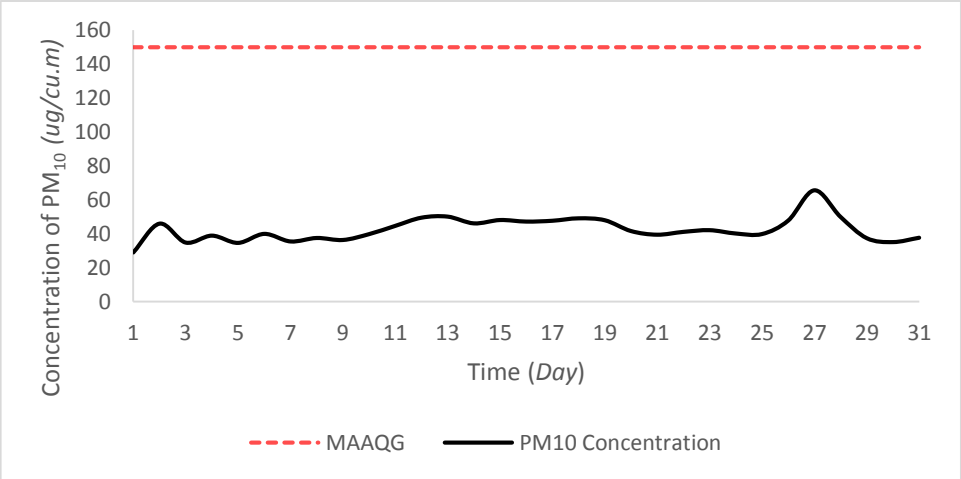


Figure A-69: Concentration of PM_{10} versus time in May 2008 at Station CA0024

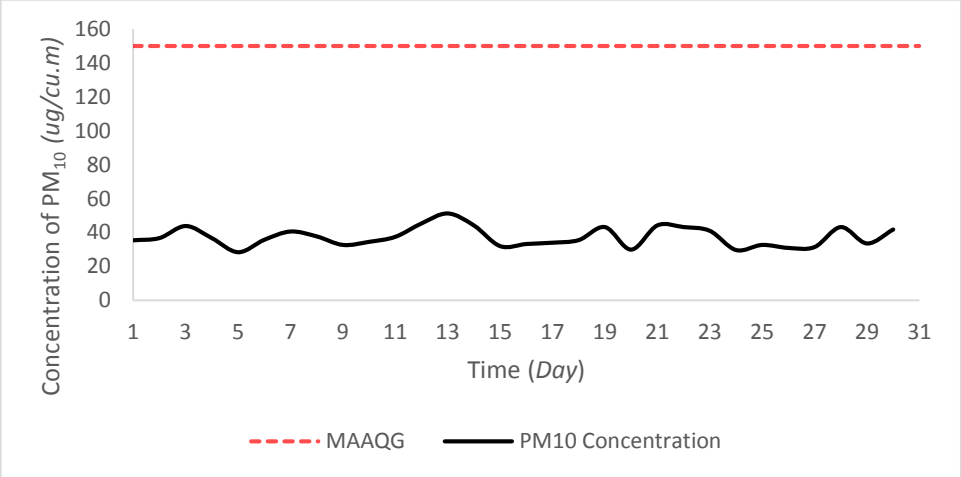


Figure A-70: Concentration of PM_{10} versus time in June 2008 at Station CA0024

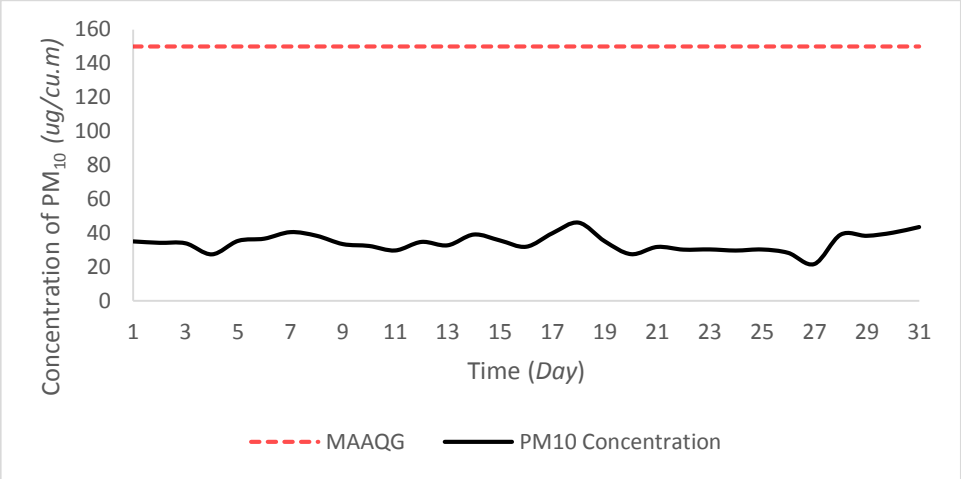


Figure A-71: Concentration of PM_{10} versus time in July 2008 at Station CA0024

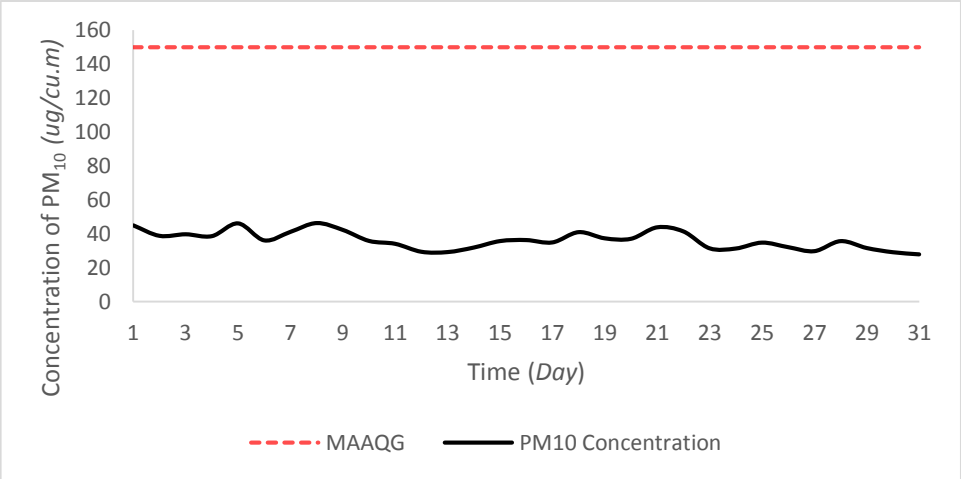


Figure A-72: Concentration of PM_{10} versus time in August 2008 at Station CA0024

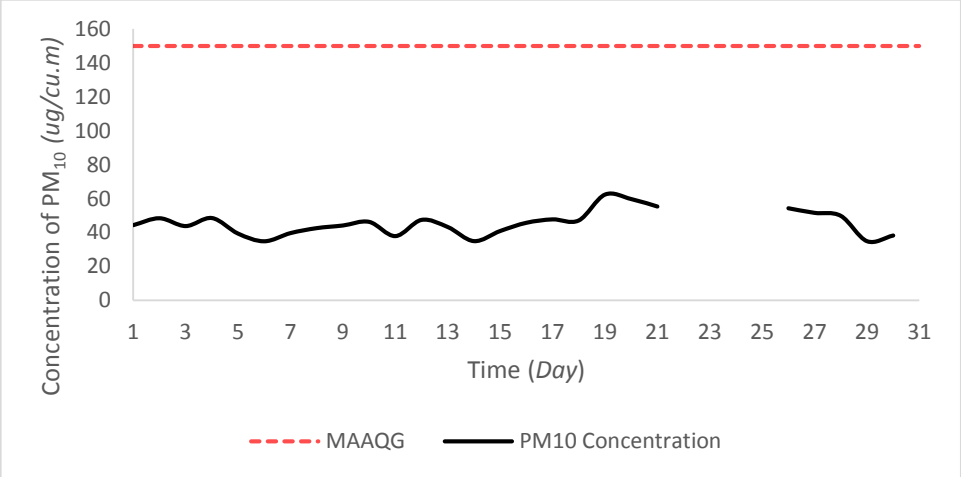


Figure A-73: Concentration of PM_{10} versus time in September 2008 at Station CA0024

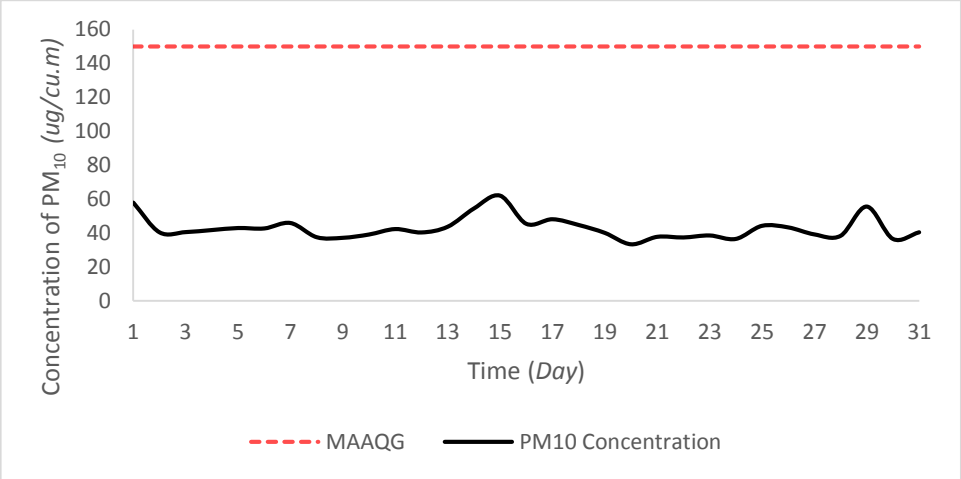


Figure A-74: Concentration of PM_{10} versus time in October 2008 at Station CA0024

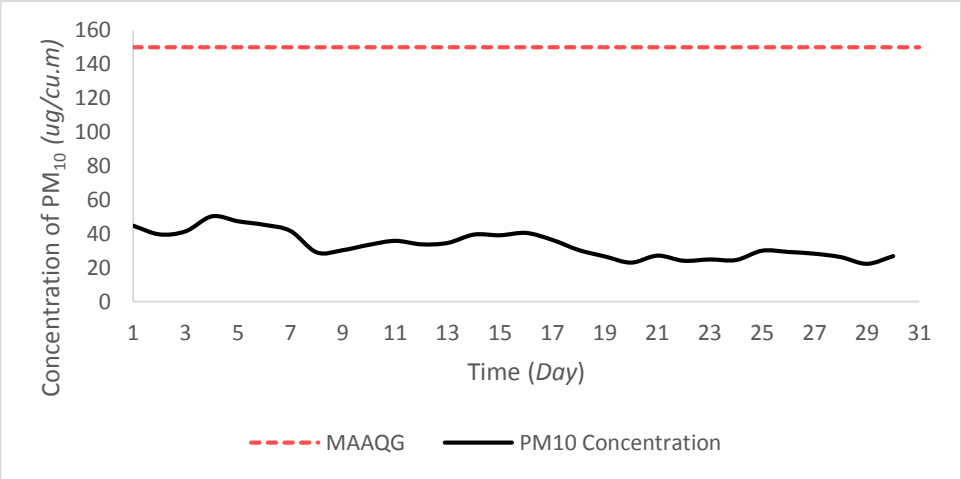


Figure A-75: Concentration of PM_{10} versus time in November 2008 at Station CA0024

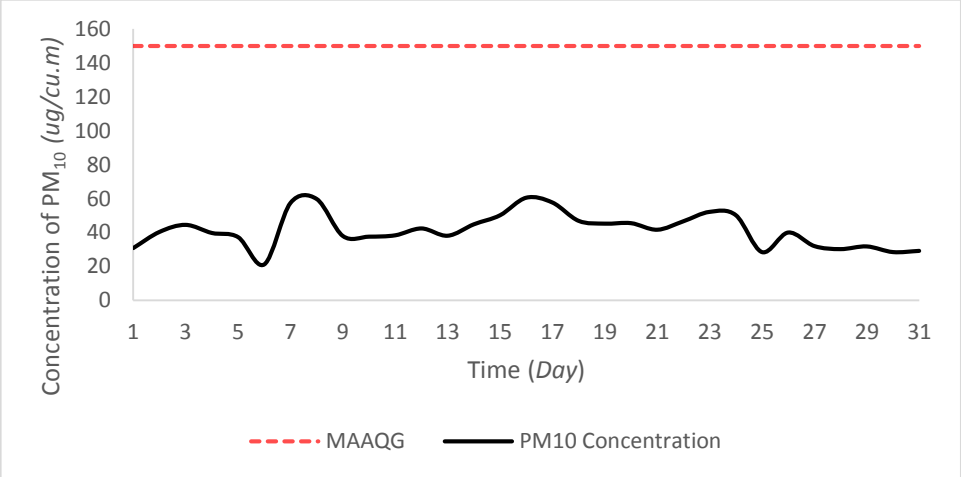


Figure A-76: Concentration of PM_{10} versus time in December 2008 at Station CA0024

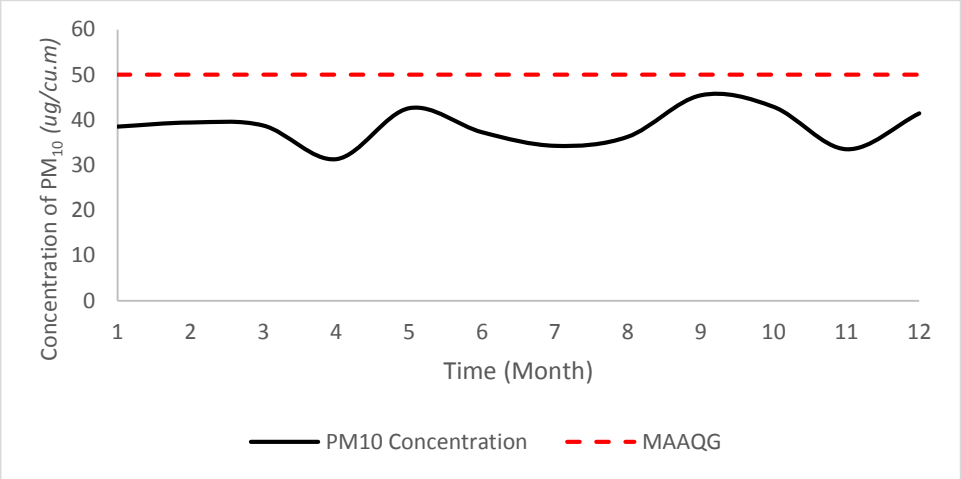


Figure A-77: Concentration of PM_{10} versus time in Year 2008 at Station CA0024

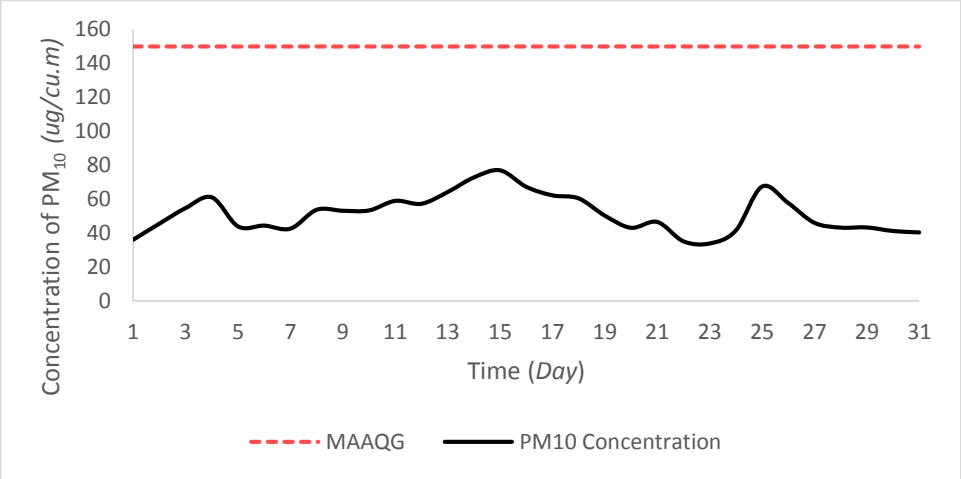


Figure A-78: Concentration of PM_{10} versus time in January 2009 at Station CA0024

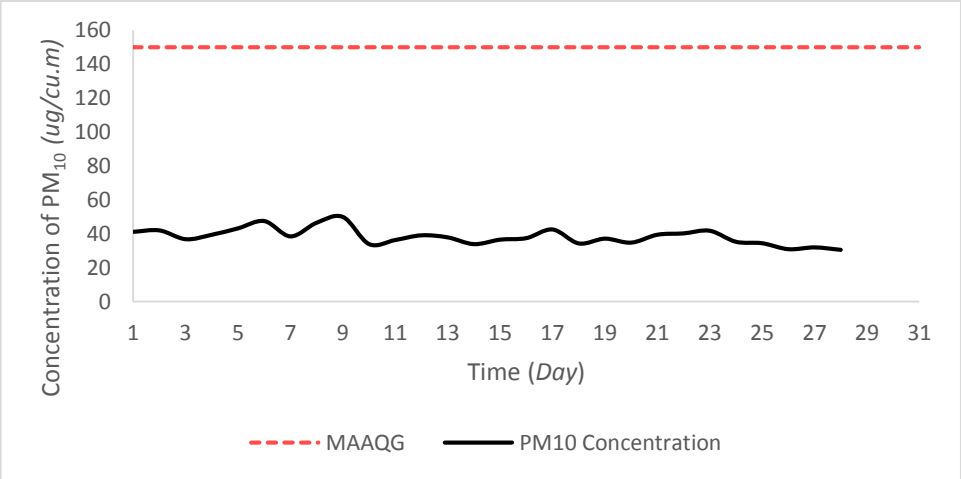


Figure A-79: Concentration of PM_{10} versus time in February 2009 at Station CA0024

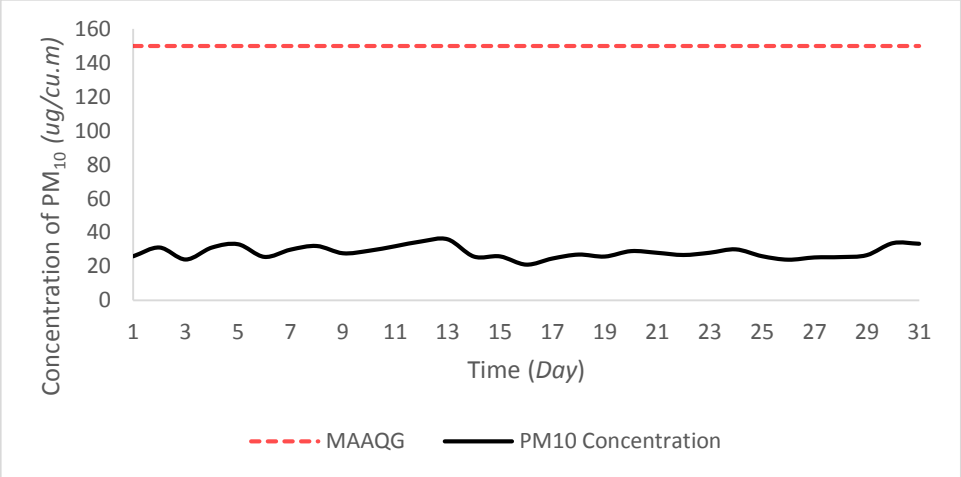


Figure A-80: Concentration of PM_{10} versus time in March 2009 at Station CA0024

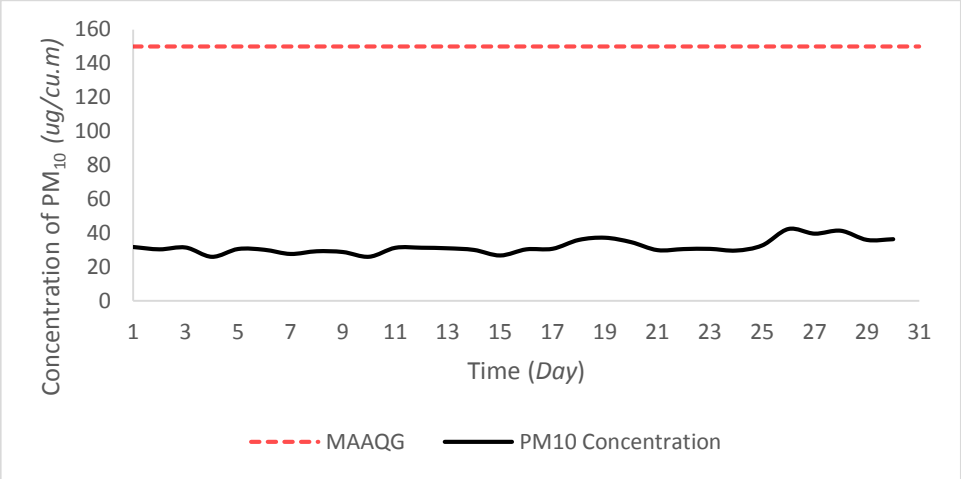


Figure A-81: Concentration of PM_{10} versus time in April 2009 at Station CA0024

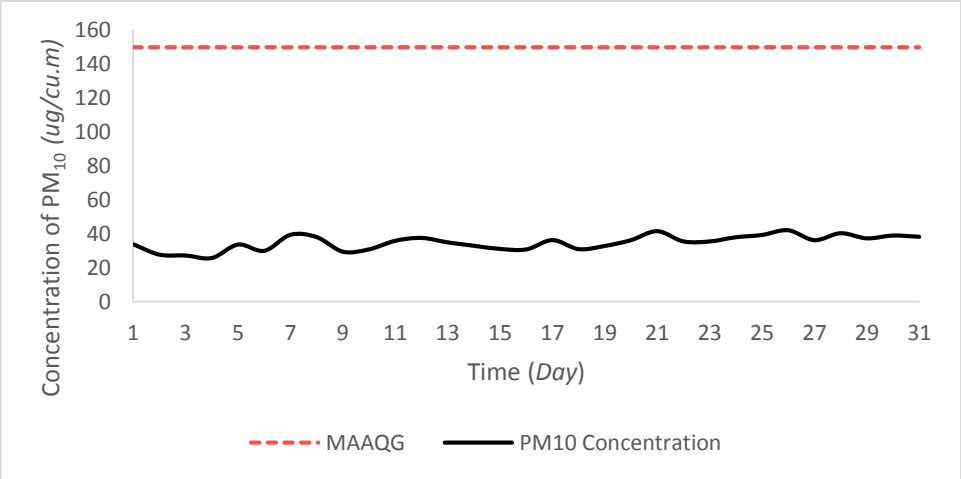


Figure A-82: Concentration of PM_{10} versus time in May 2009 at Station CA0024

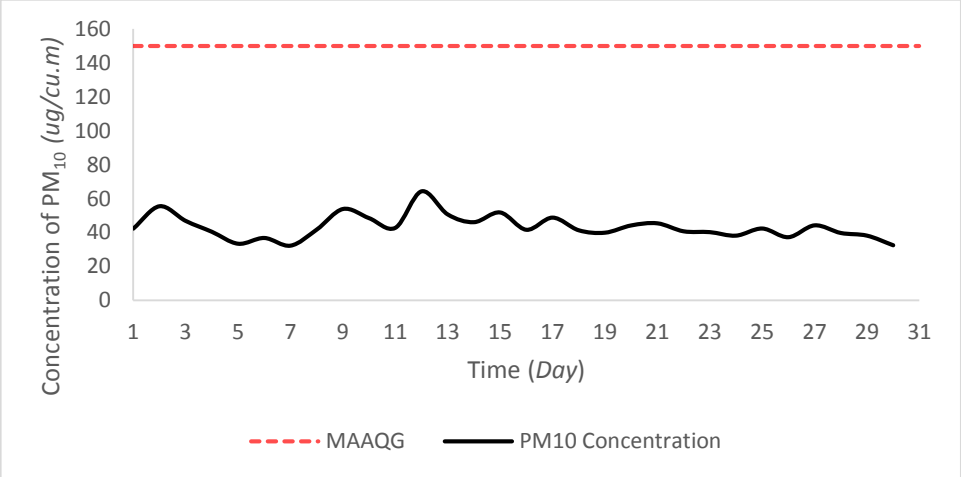


Figure A-83: Concentration of PM_{10} versus time in June 2009 at Station CA0024

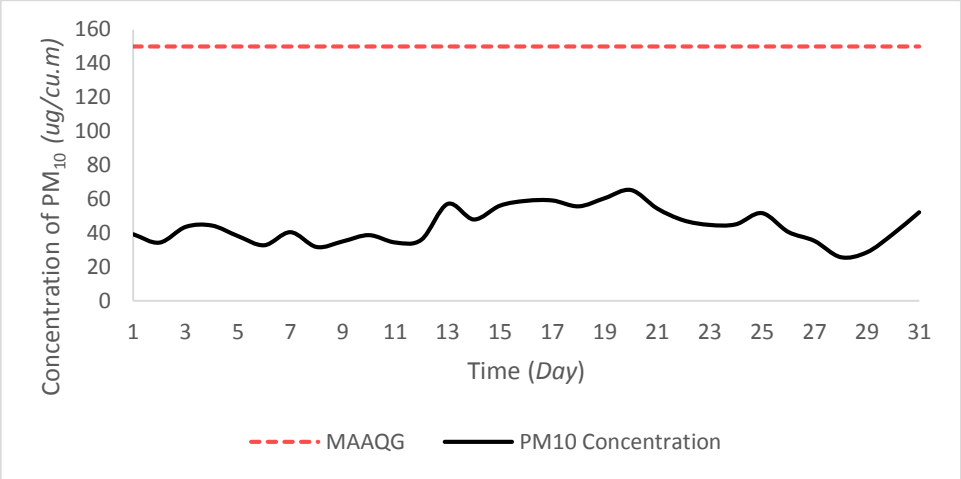


Figure A-84: Concentration of PM_{10} versus time in July 2009 at Station CA0024

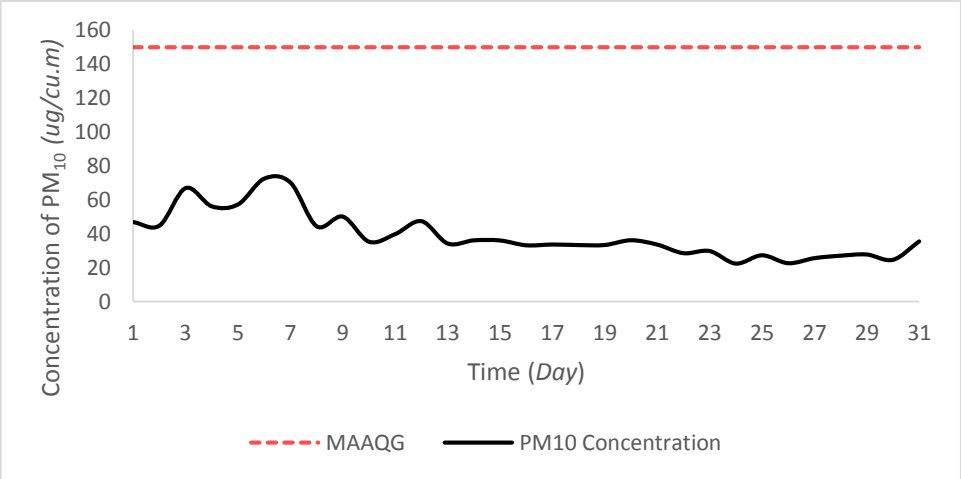


Figure A-85: Concentration of PM_{10} versus time in August 2009 at Station CA0024

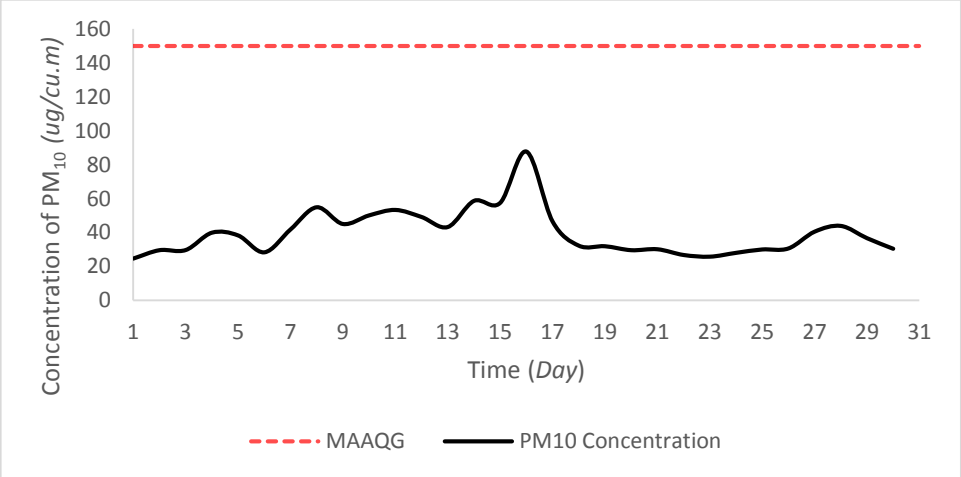


Figure A-86: Concentration of PM_{10} versus time in September 2009 at Station CA0024

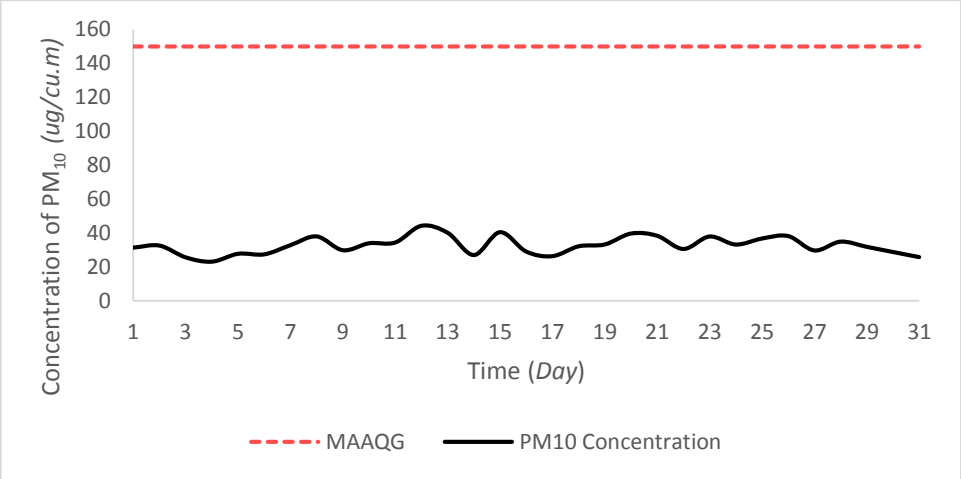


Figure A-87: Concentration of PM_{10} versus time in October 2009 at Station CA0024

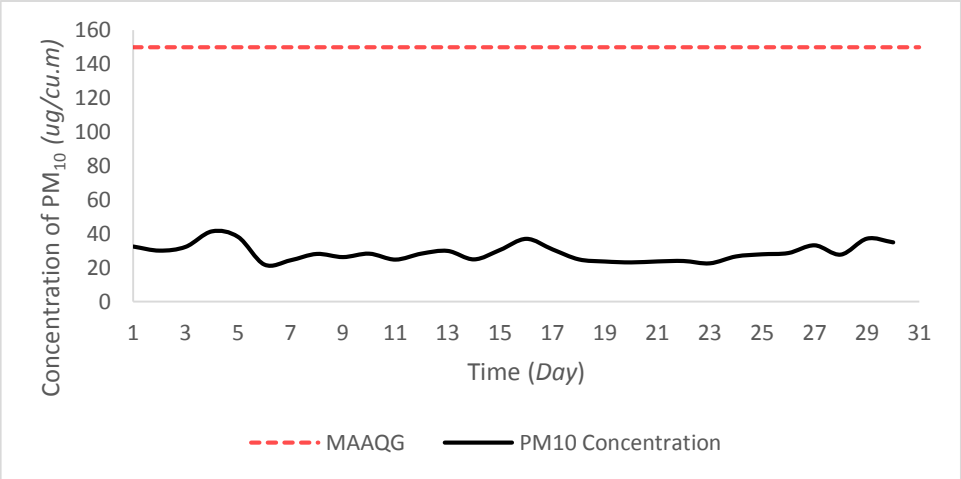


Figure A-88: Concentration of PM_{10} versus time in November 2009 at Station CA0024

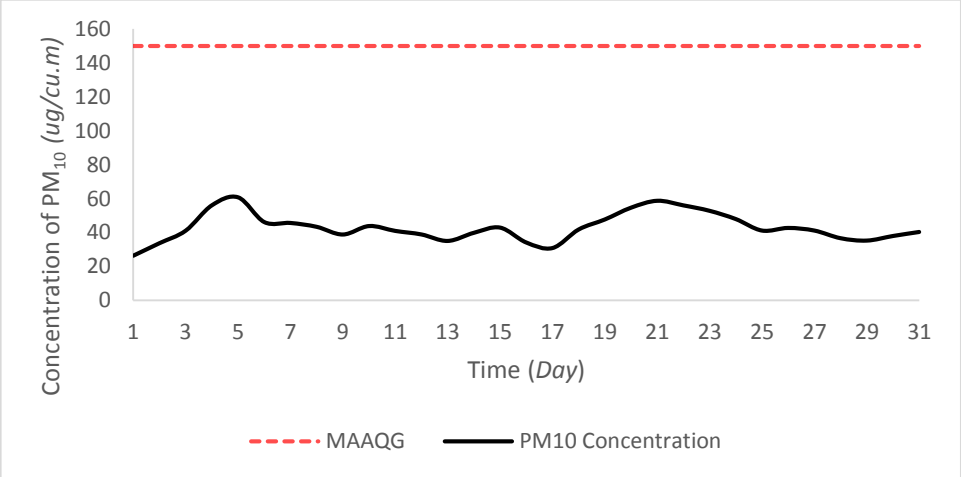


Figure A-89: Concentration of PM_{10} versus time in December 2009 at Station CA0024

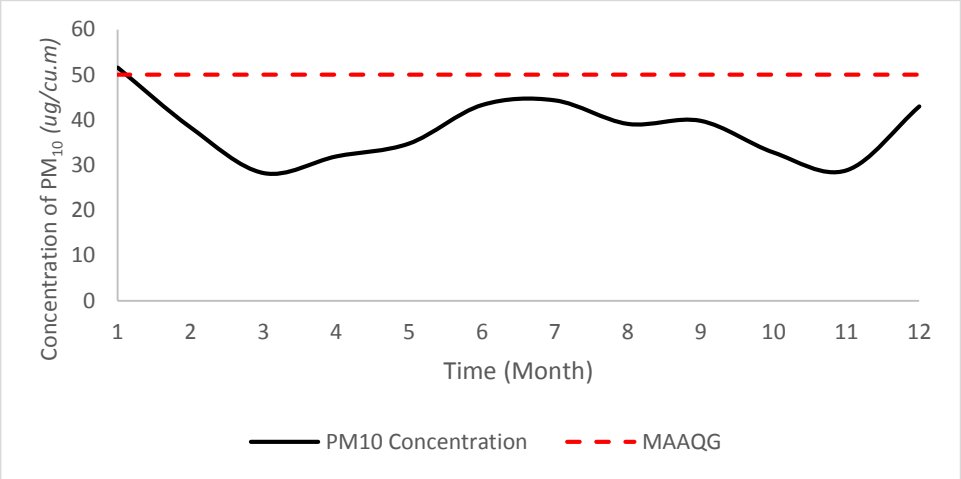


Figure A-90: Concentration of PM_{10} versus time in Year 2009 at Station CA0024

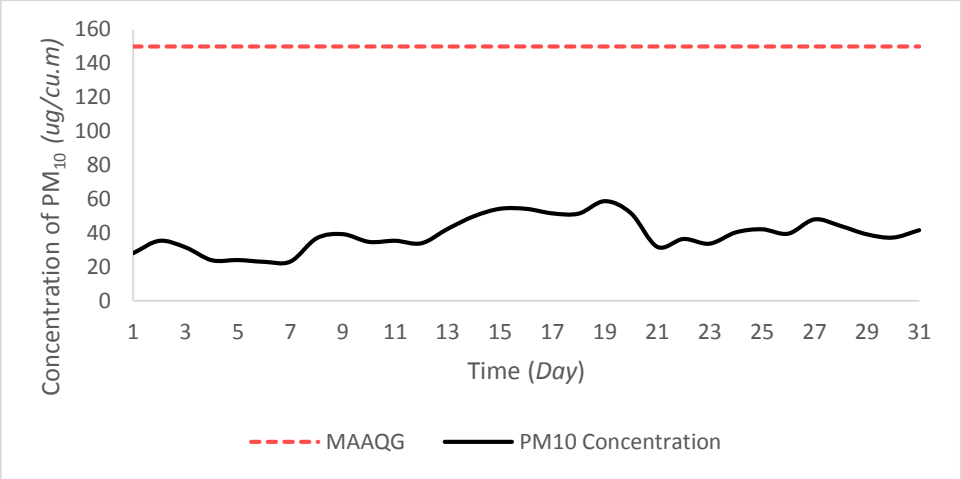


Figure A-91: Concentration of PM_{10} versus time in January 2010 at Station CA0024

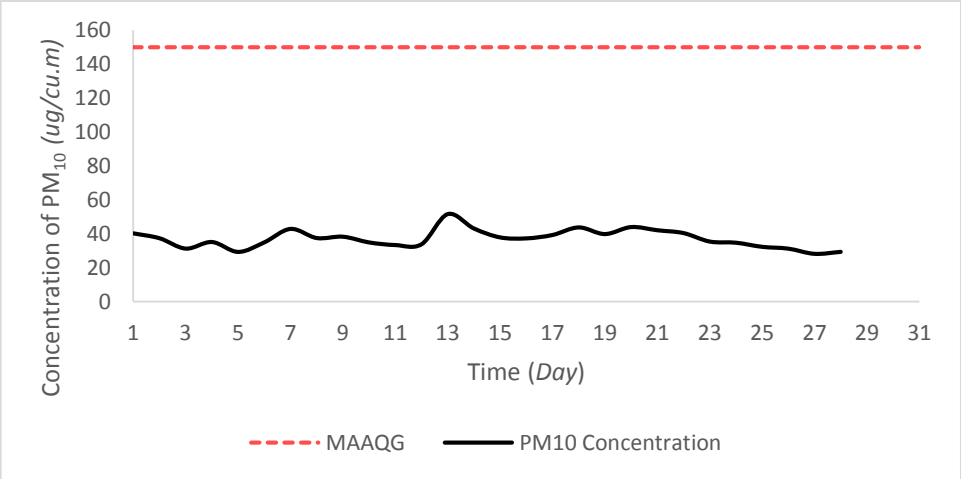


Figure A-92: Concentration of PM_{10} versus time in February 2010 at Station CA0024

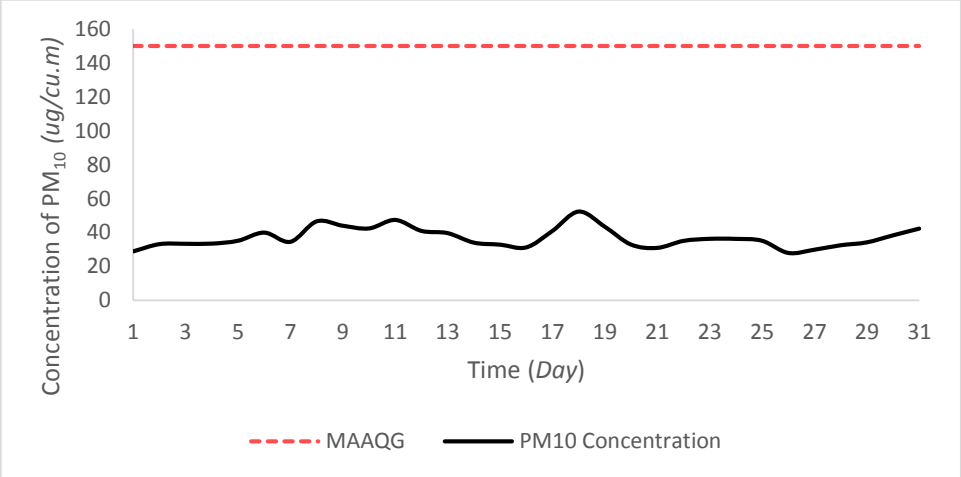


Figure A-93: Concentration of PM_{10} versus time in March 2010 at Station CA0024

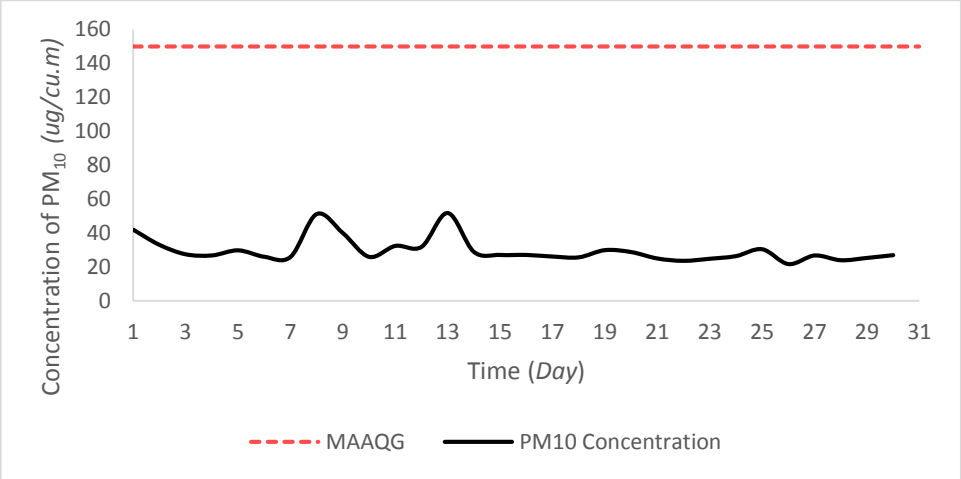


Figure A-94: Concentration of PM_{10} versus time in April 2010 at Station CA0024

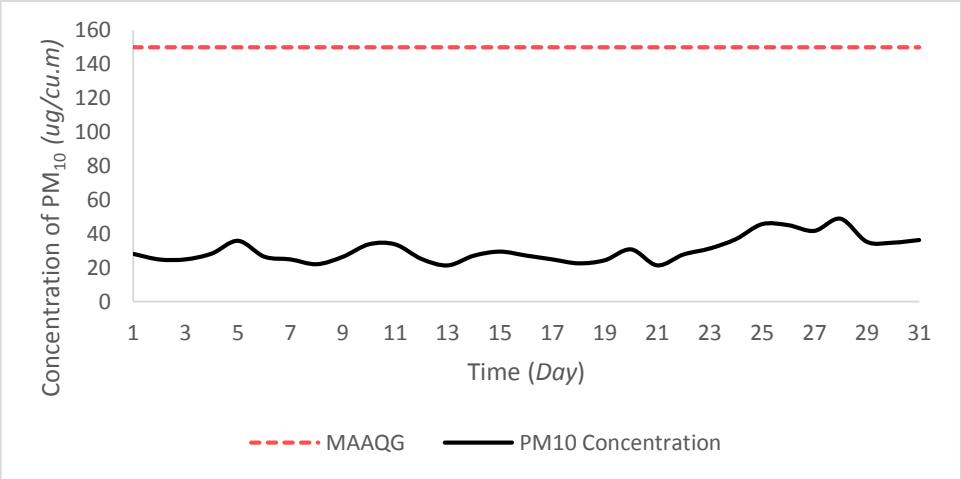


Figure A-95: Concentration of PM_{10} versus time in May 2010 at Station CA0024

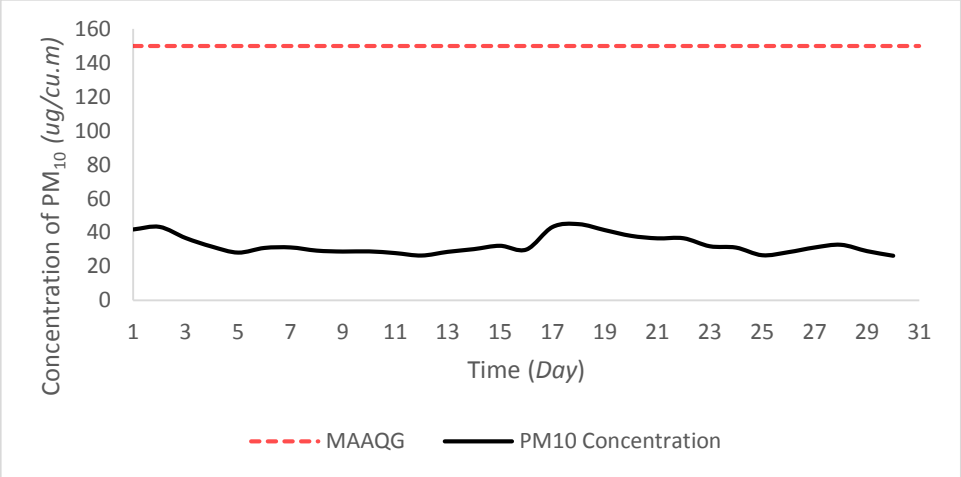


Figure A-96: Concentration of PM_{10} versus time in June 2010 at Station CA0024

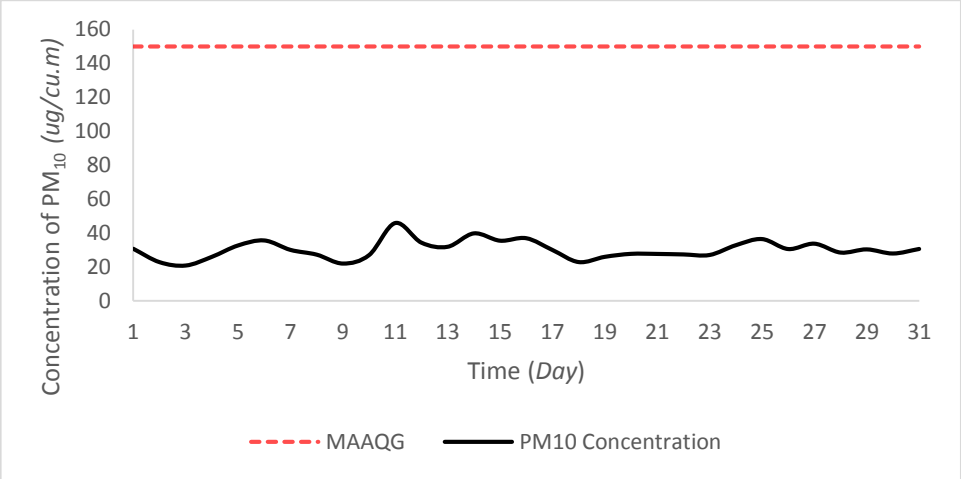


Figure A-97: Concentration of PM_{10} versus time in July 2010 at Station CA0024

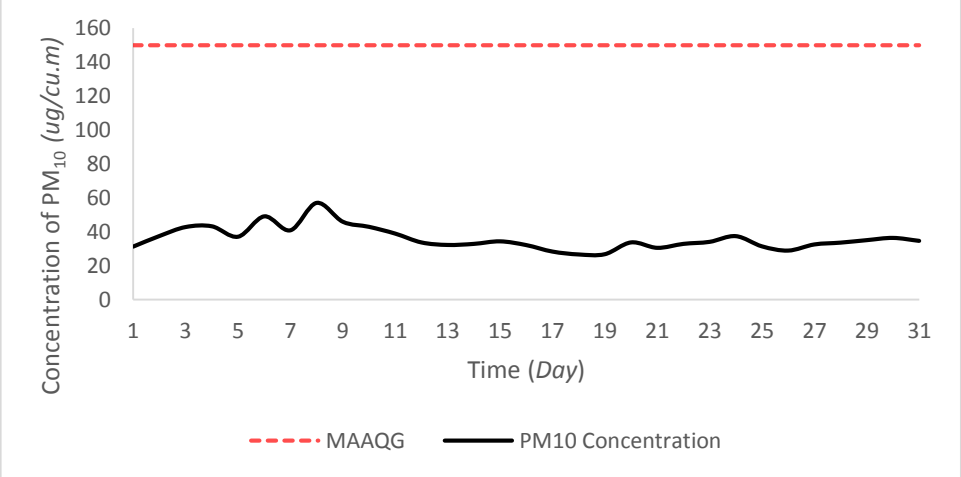


Figure A-98: Concentration of PM_{10} versus time in August 2010 at Station CA0024

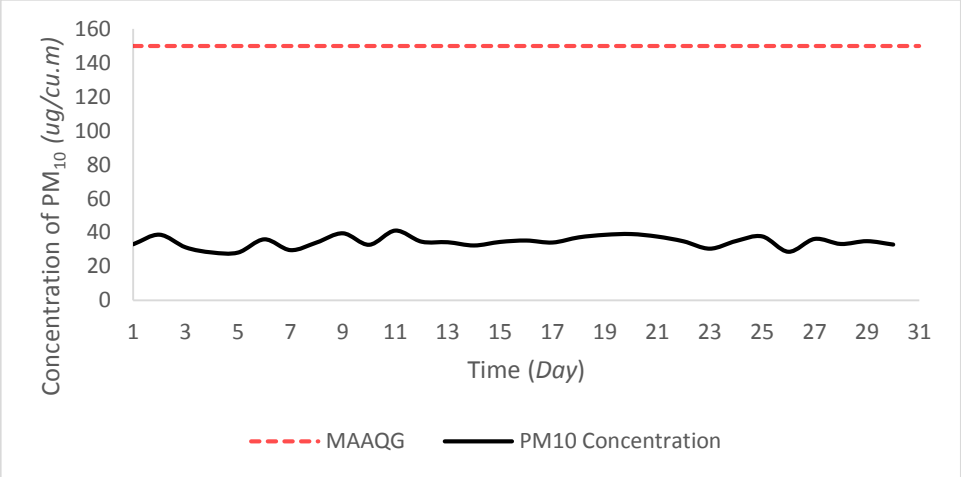


Figure A-99: Concentration of PM_{10} versus time in September 2010 at Station CA0024

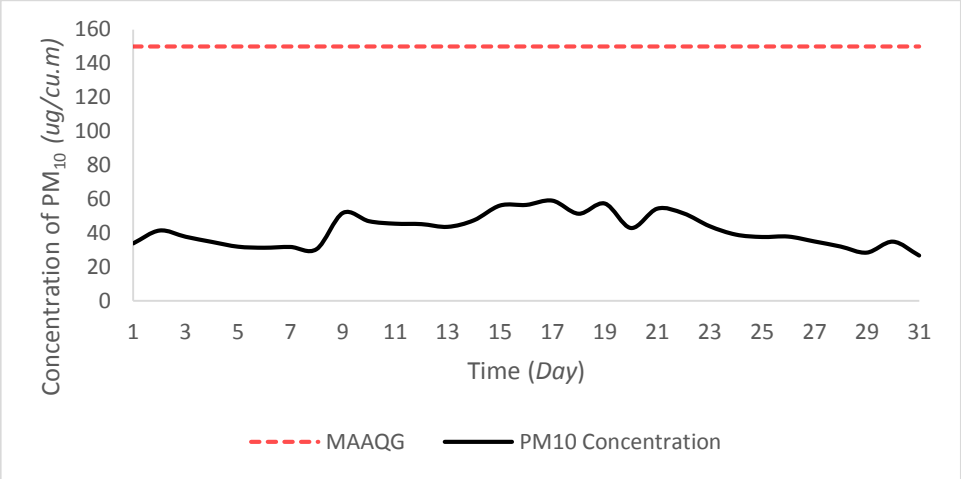


Figure A-100: Concentration of PM_{10} versus time in October 2010 at Station CA0024

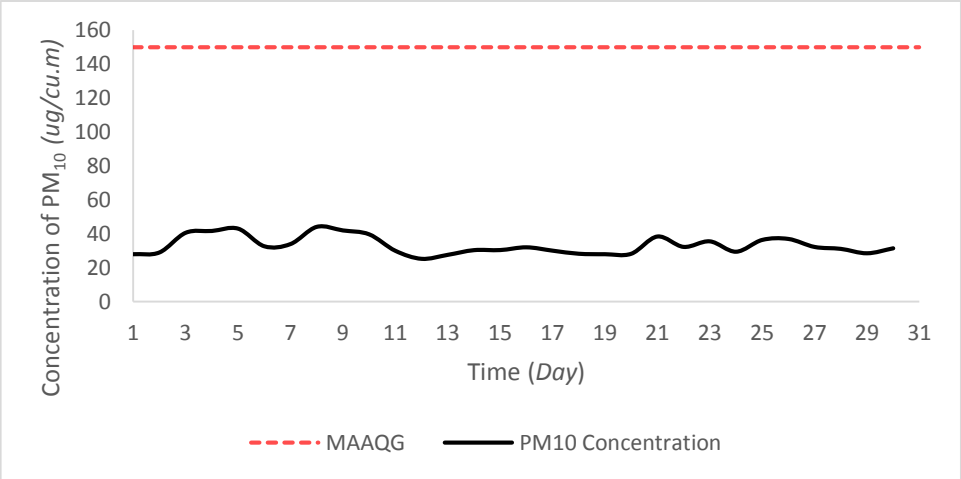


Figure A-101: Concentration of PM_{10} versus time in November 2010 at Station CA0024

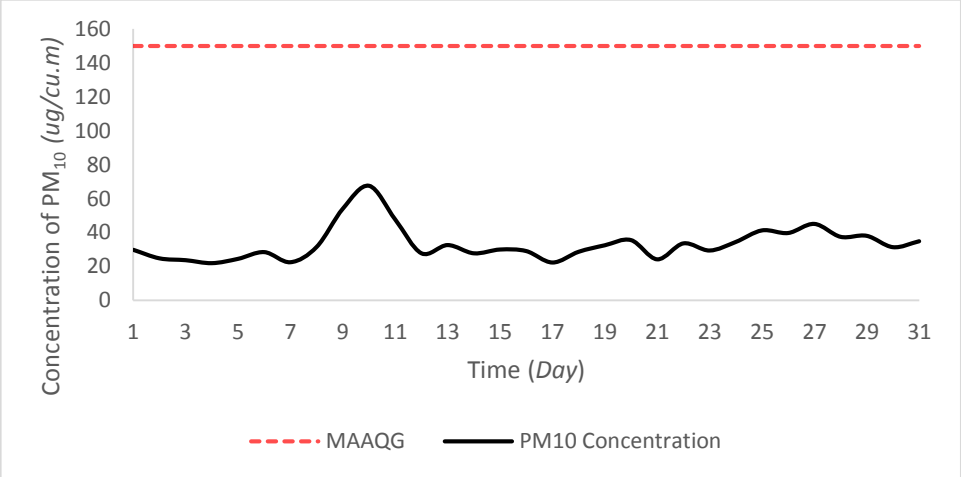


Figure A-102: Concentration of PM_{10} versus time in December 2010 at Station CA0024

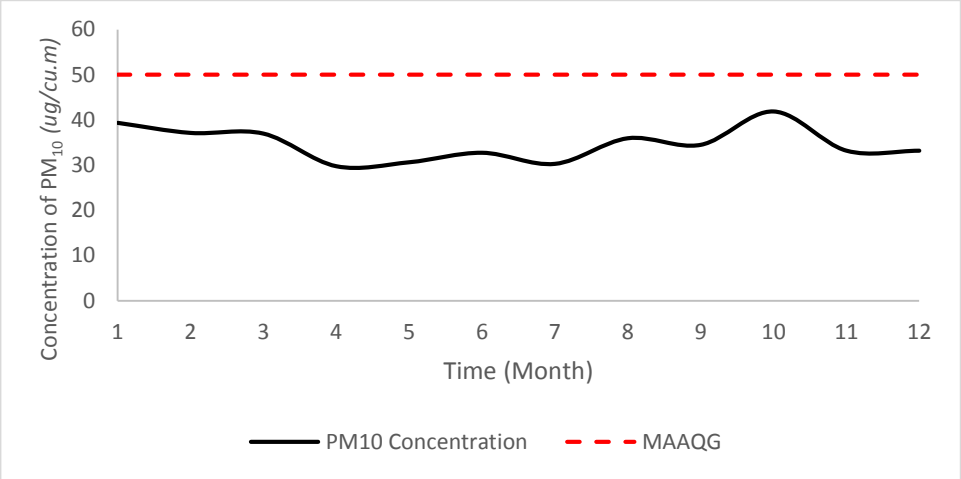


Figure A-103: Concentration of PM_{10} versus time in Year 2010 at Station CA0024

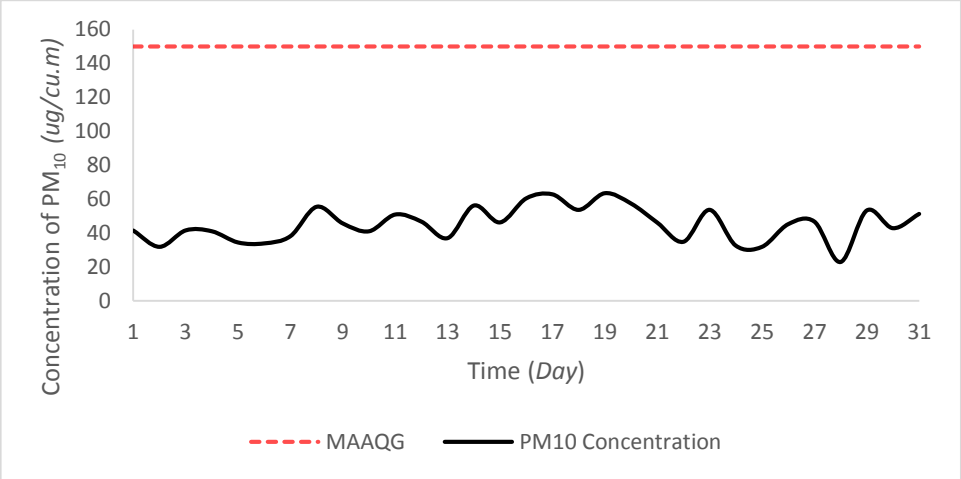


Figure A-104: Concentration of PM_{10} versus time in January 2008 at Station CA0027

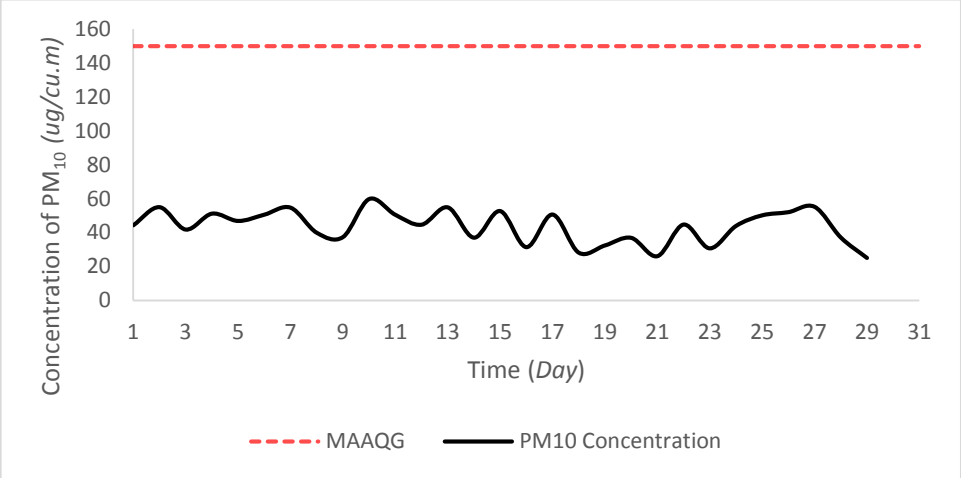


Figure A-105: Concentration of PM_{10} versus time in February 2008 at Station CA0027

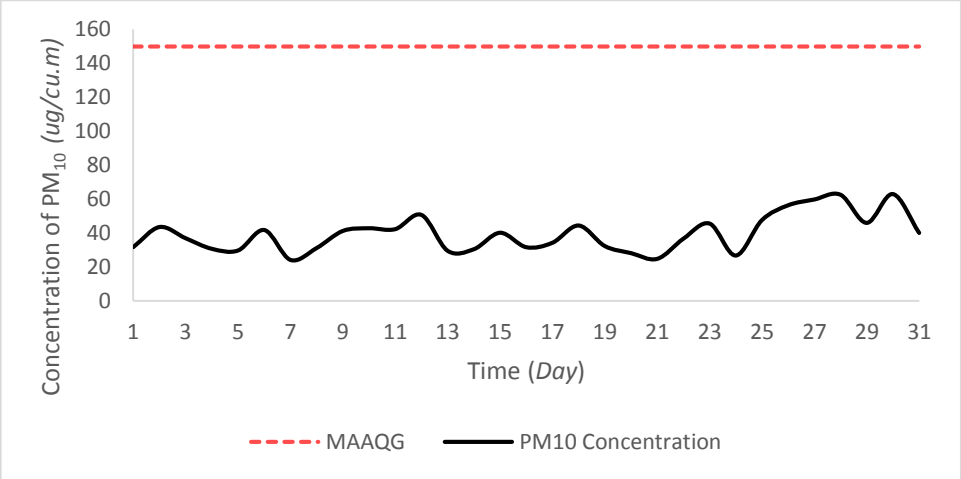


Figure A-106: Concentration of PM_{10} versus time in March 2008 at Station CA0027

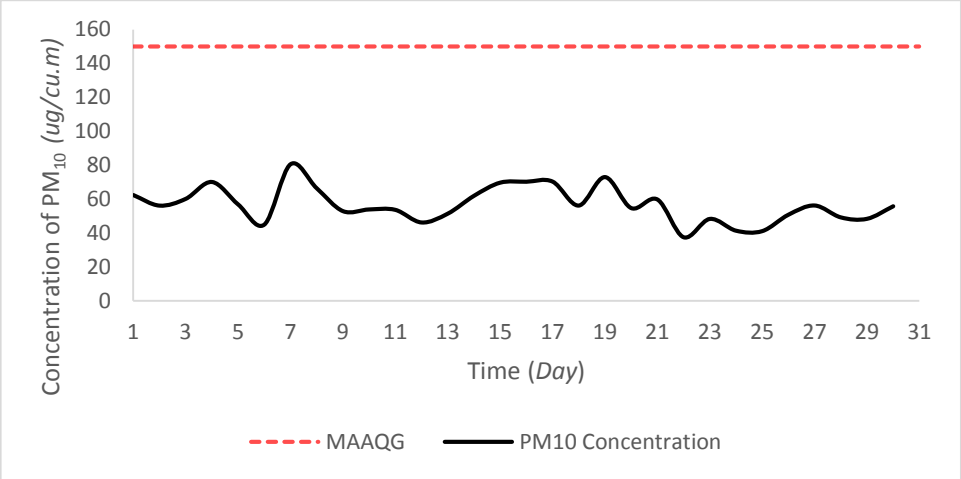


Figure A-107: Concentration of PM_{10} versus time in April 2008 at Station CA0027

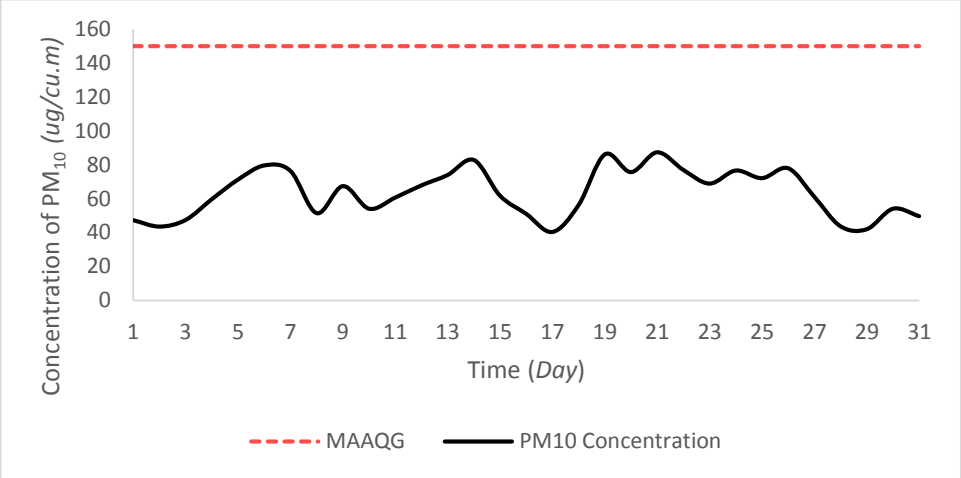


Figure A-108: Concentration of PM_{10} versus time in May 2008 at Station CA0027

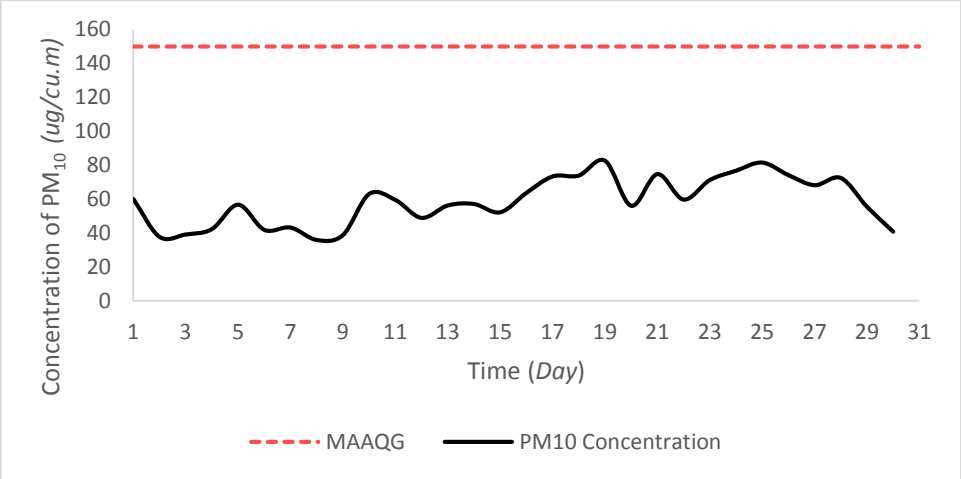


Figure A-109: Concentration of PM_{10} versus time in June 2008 at Station CA0027

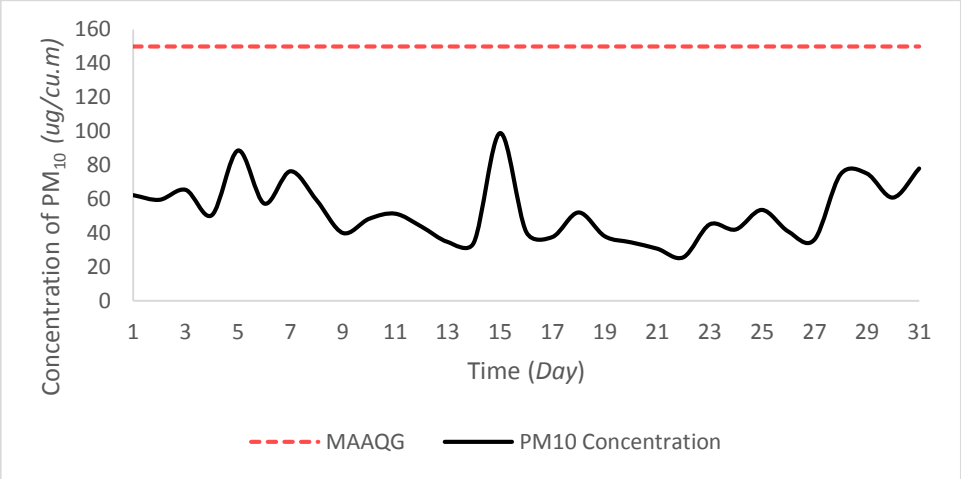


Figure A-110: Concentration of PM_{10} versus time in July 2008 at Station CA0027

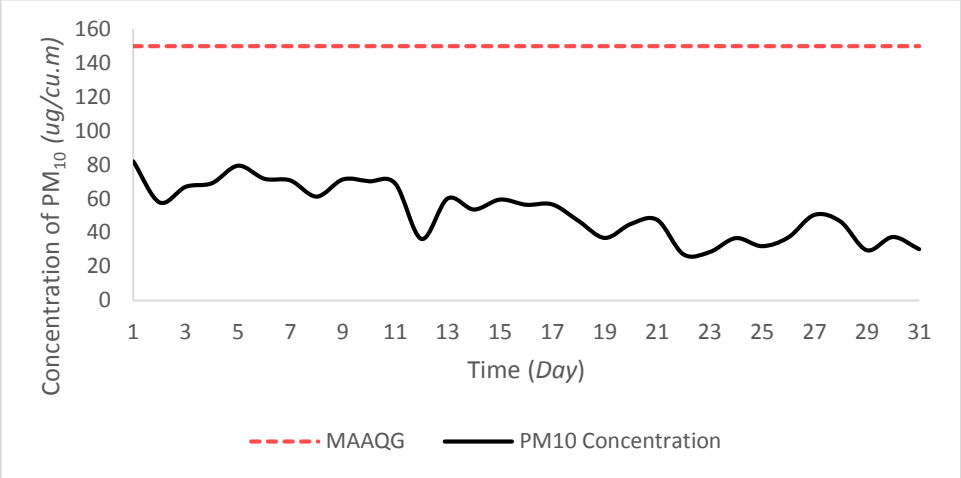


Figure A-111: Concentration of PM_{10} versus time in August 2008 at Station CA0027

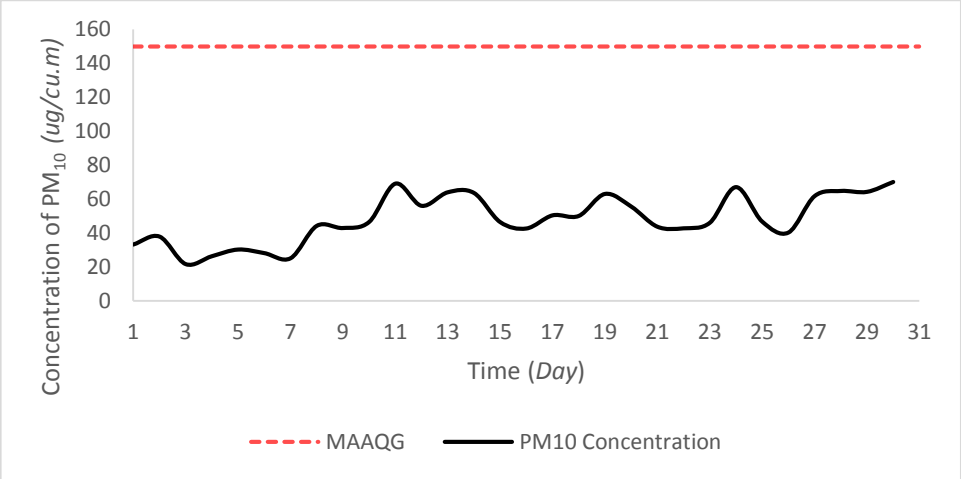


Figure A-112: Concentration of PM_{10} versus time in September 2008 at Station CA0027

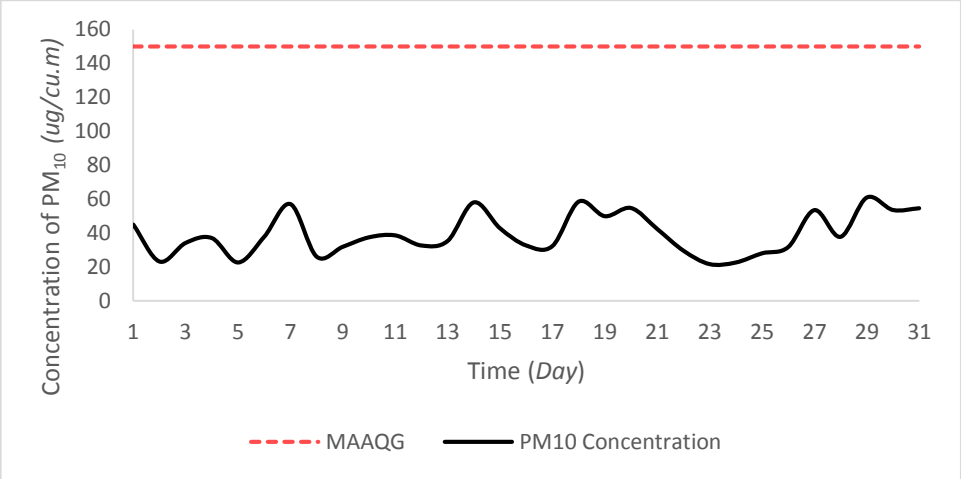


Figure A-113: Concentration of PM_{10} versus time in October 2008 at Station CA0027

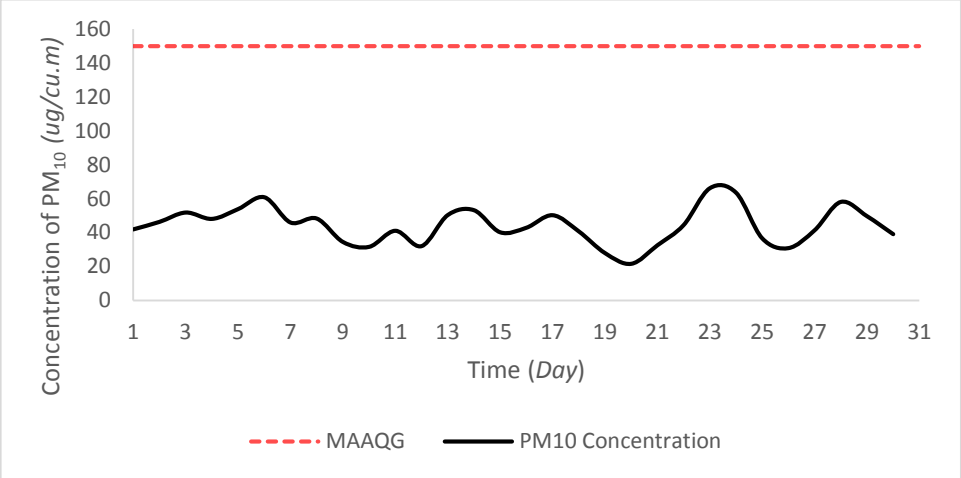


Figure A-114: Concentration of PM_{10} versus time in November 2008 at Station CA0027

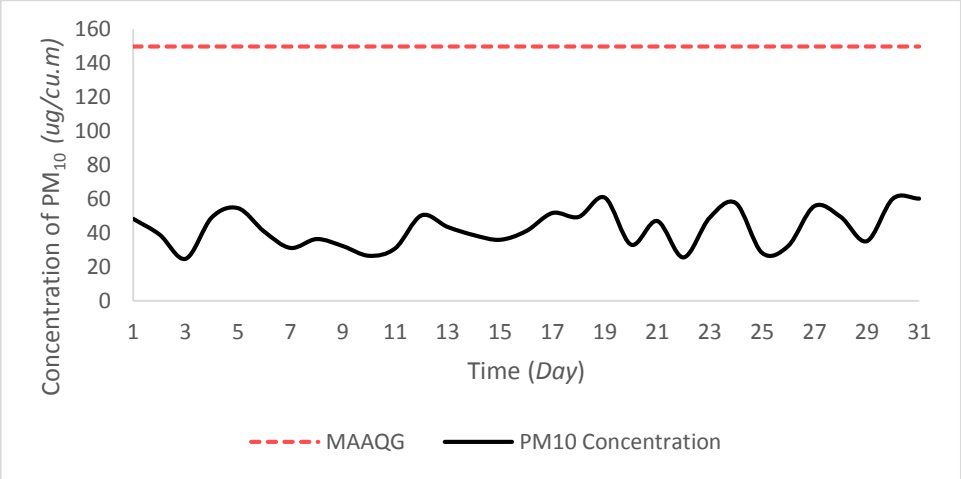


Figure A-115: Concentration of PM_{10} versus time in December 2008 at Station CA0027

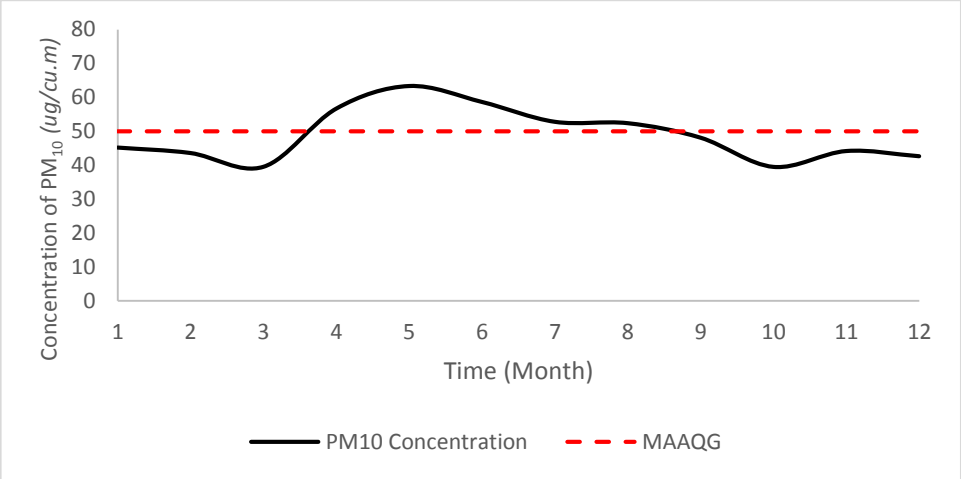


Figure A-116: Concentration of PM_{10} versus time in Year 2008 at Station CA0027

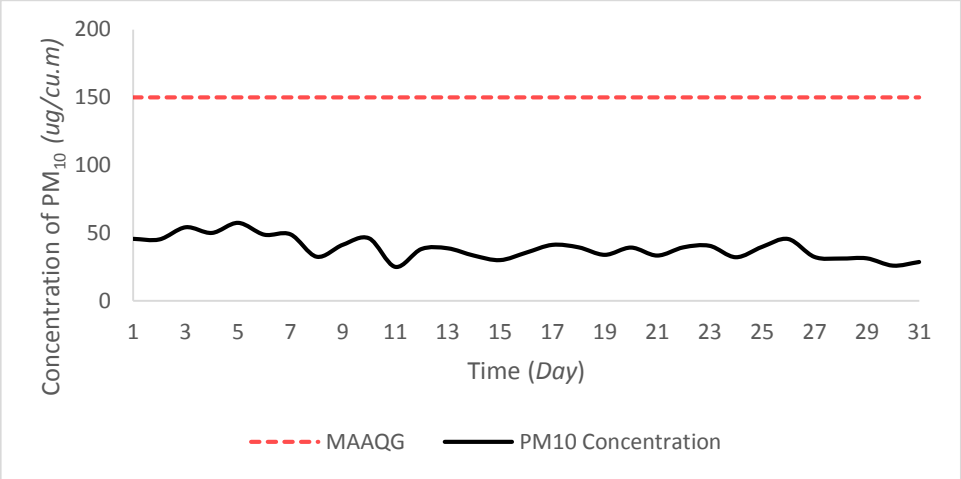


Figure A-117: Concentration of PM_{10} versus time in January 2009 at Station CA0027

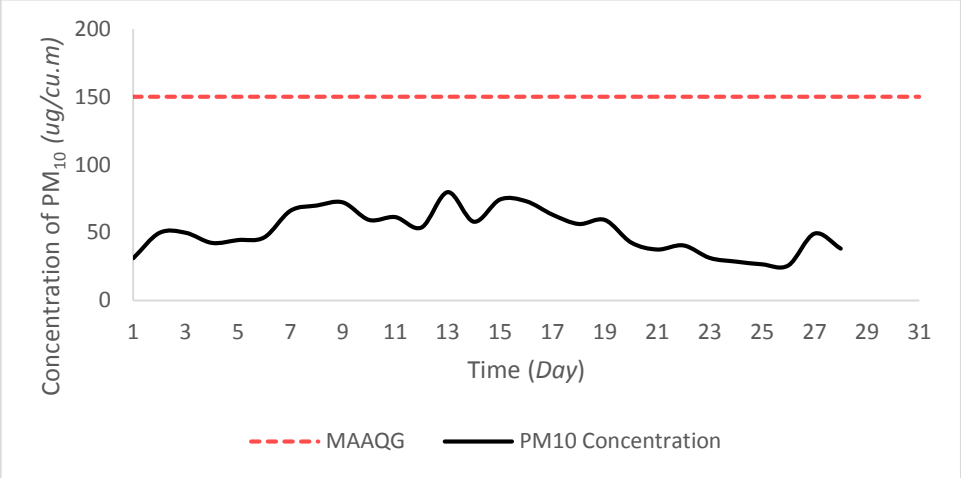


Figure A-118: Concentration of PM_{10} versus time in February 2009 at Station CA0027

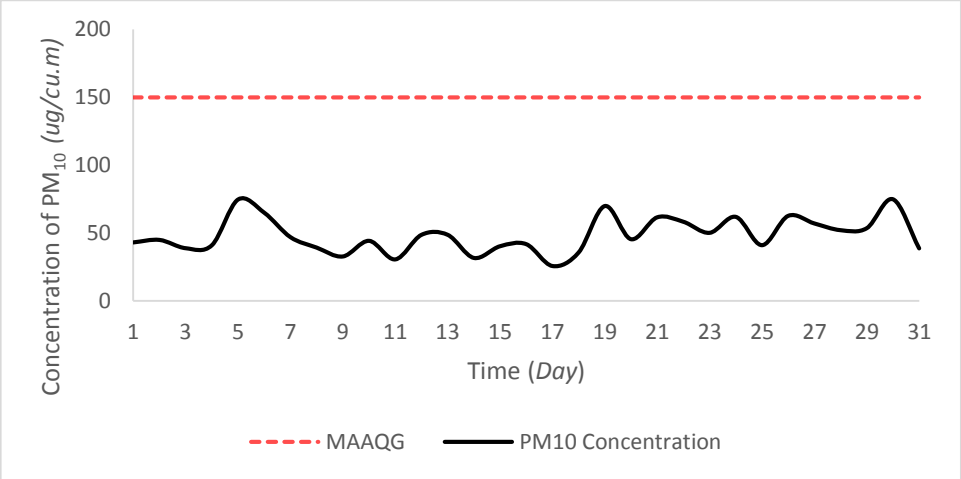


Figure A-119: Concentration of PM_{10} versus time in March 2009 at Station CA0027

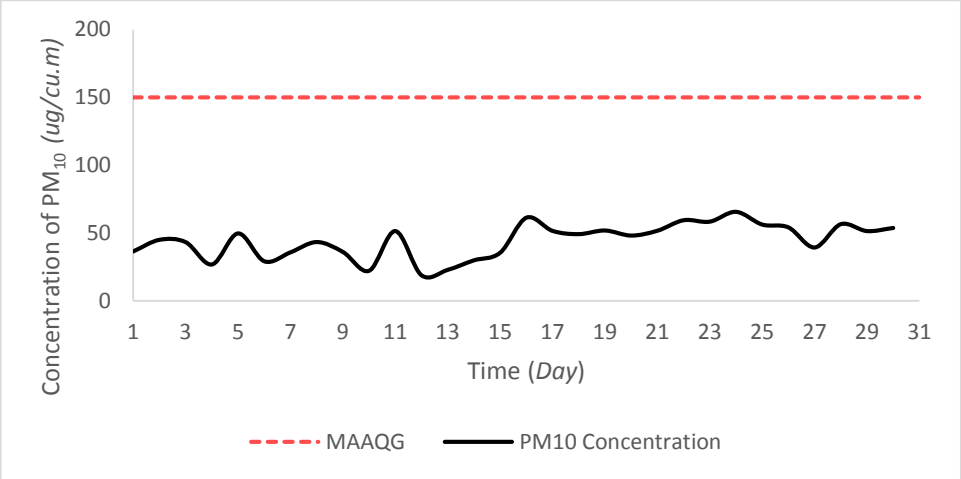


Figure A-120: Concentration of PM_{10} versus time in April 2009 at Station CA0027

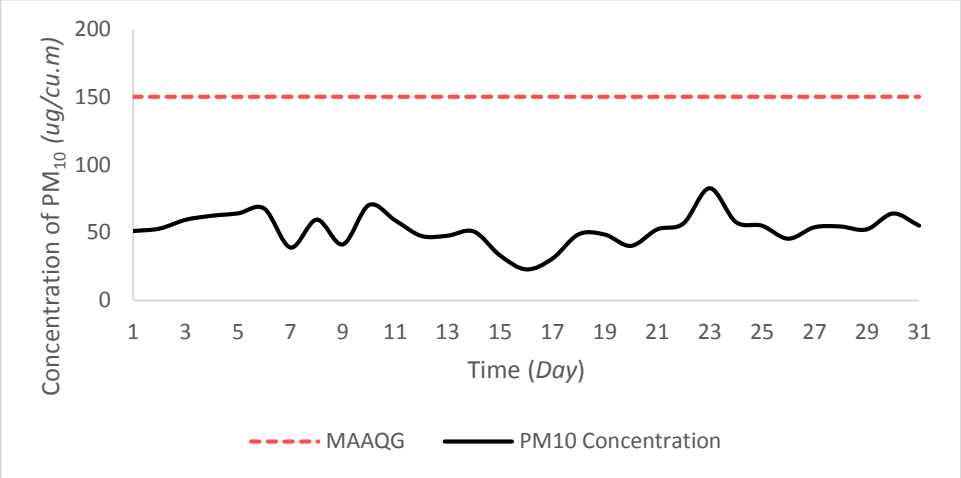


Figure A-121: Concentration of PM_{10} versus time in May 2009 at Station CA0027

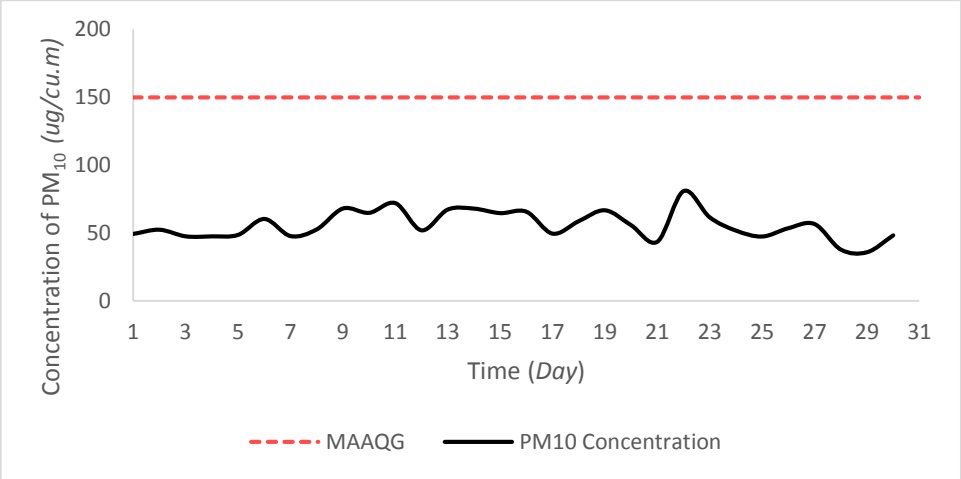


Figure A-122: Concentration of PM_{10} versus time in June 2009 at Station CA0027

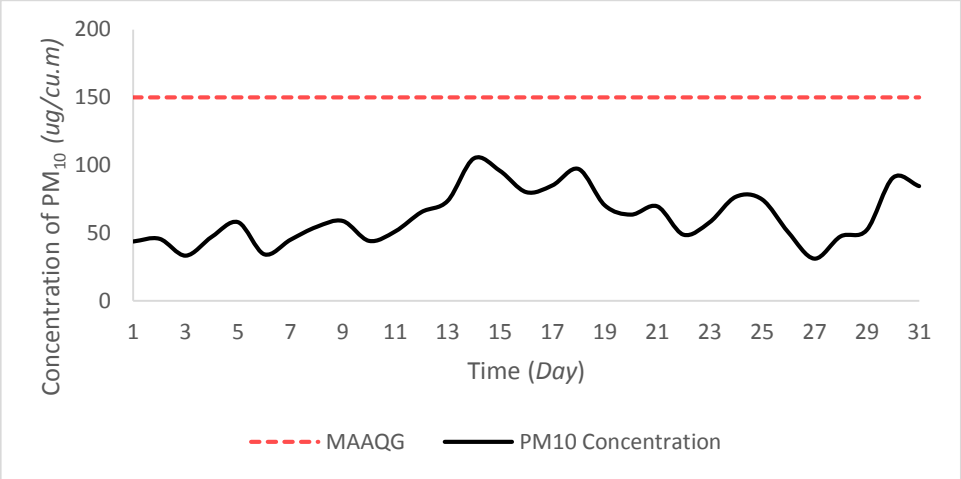


Figure A-123: Concentration of PM_{10} versus time in July 2009 at Station CA0027

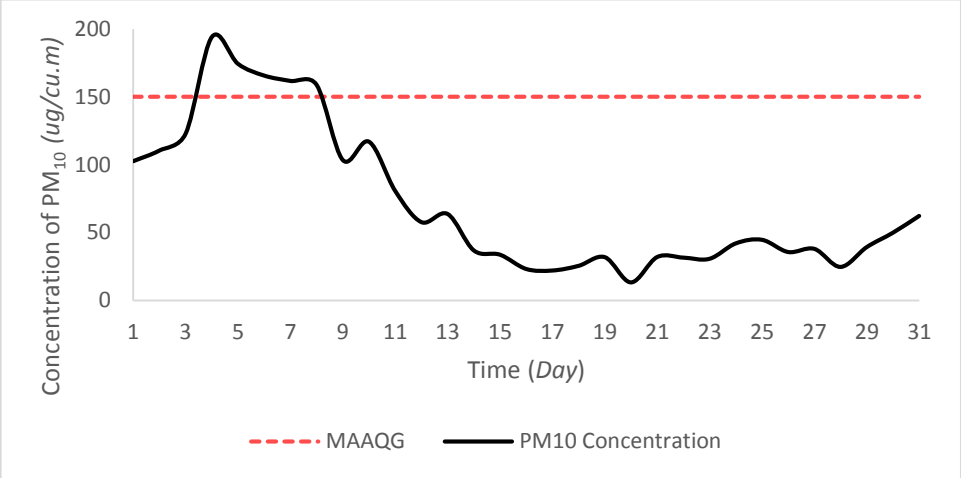


Figure A-124: Concentration of PM_{10} versus time in August 2009 at Station CA0027

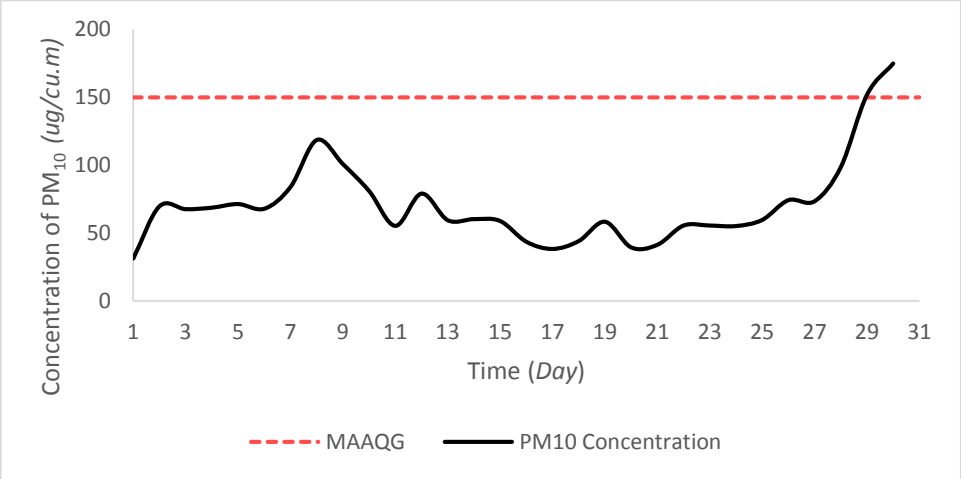


Figure A-125: Concentration of PM_{10} versus time in September 2009 at Station CA0027

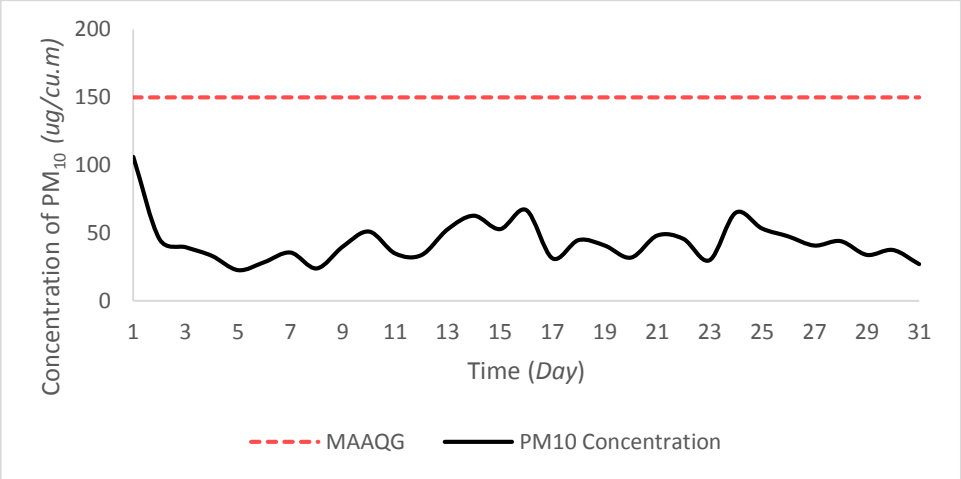


Figure A-126: Concentration of PM_{10} versus time in October 2009 at Station CA0027

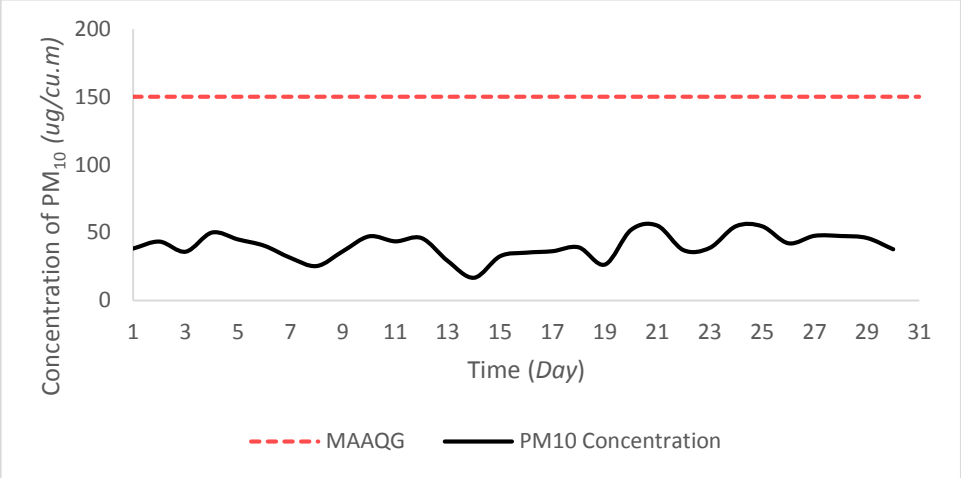


Figure A-127: Concentration of PM_{10} versus time in November 2009 at Station CA0027

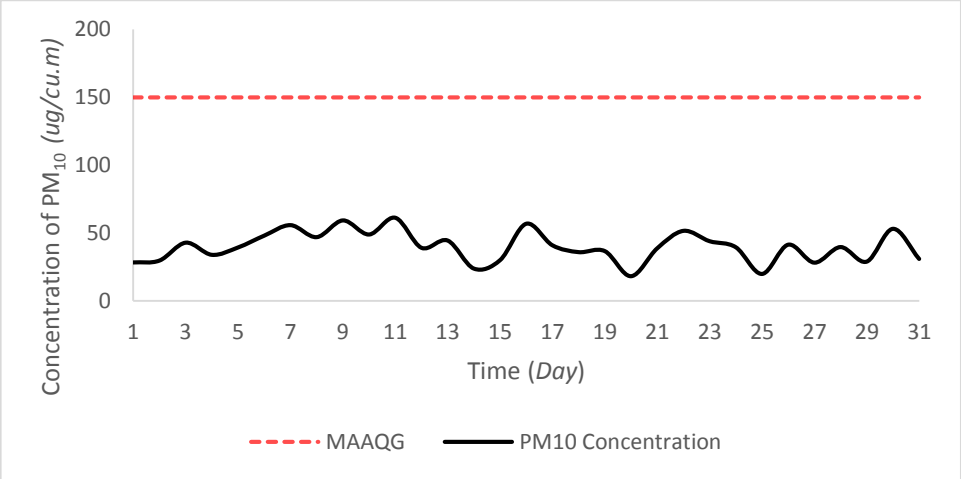


Figure A-128: Concentration of PM_{10} versus time in December 2009 at Station CA0027

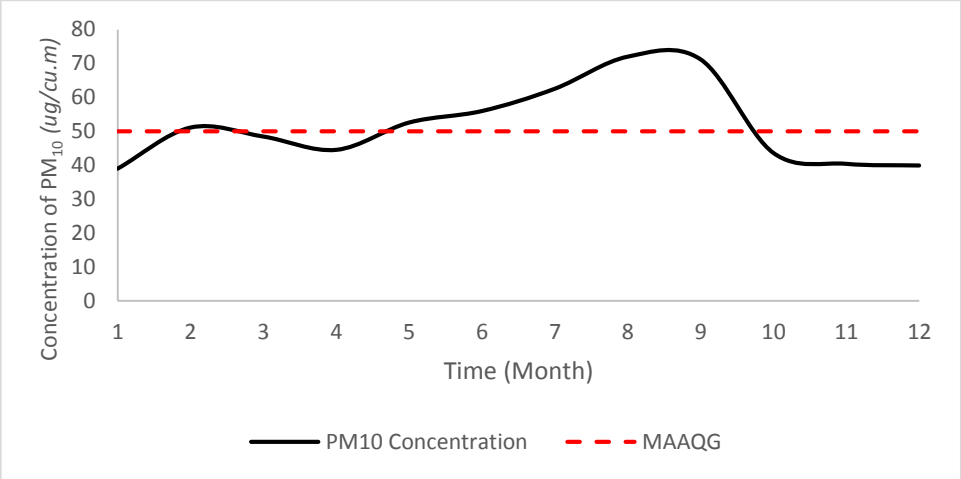


Figure A-129: Concentration of PM_{10} versus time in Year 2009 at Station CA0027

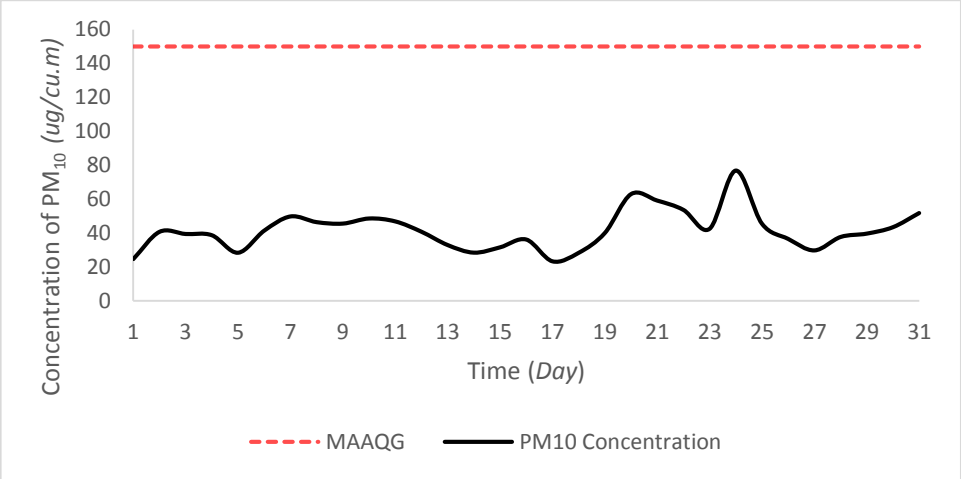


Figure A-130: Concentration of PM_{10} versus time in January 2010 at Station CA0027

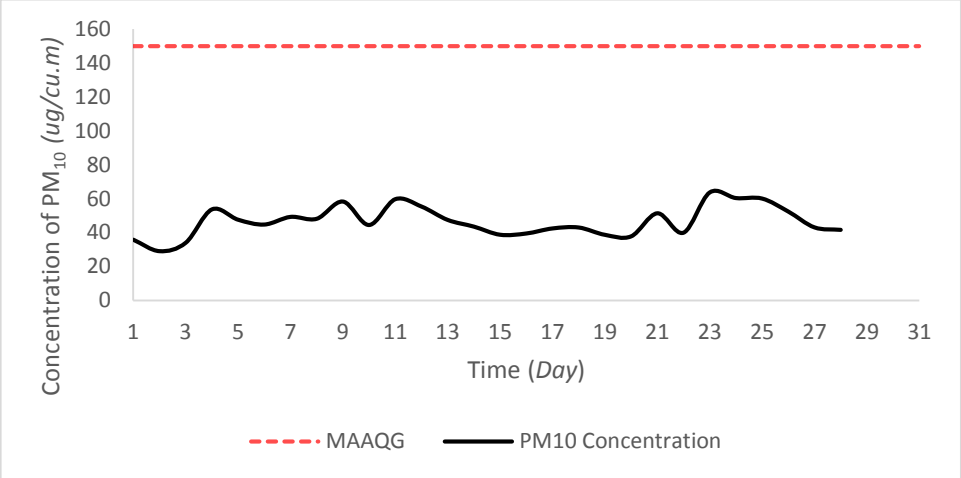


Figure A-131: Concentration of PM_{10} versus time in February 2010 at Station CA0027

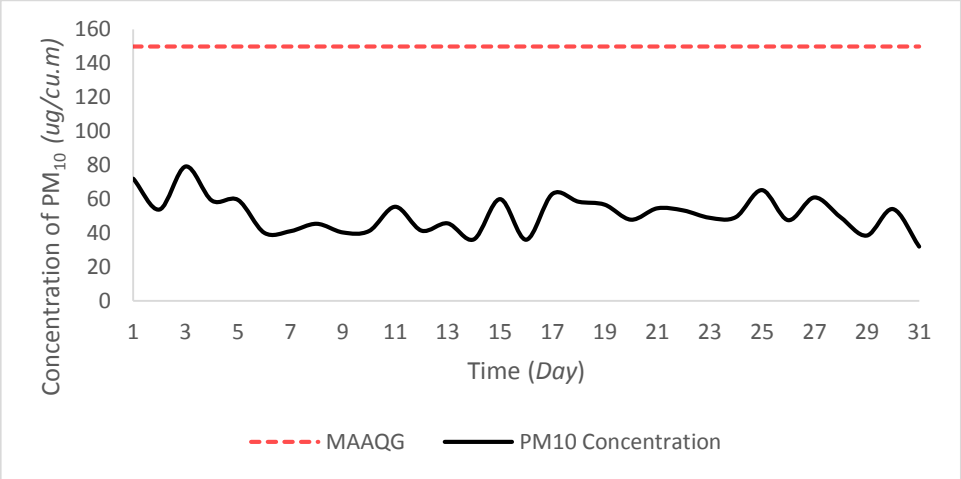


Figure A-132: Concentration of PM_{10} versus time in March 2010 at Station CA0027

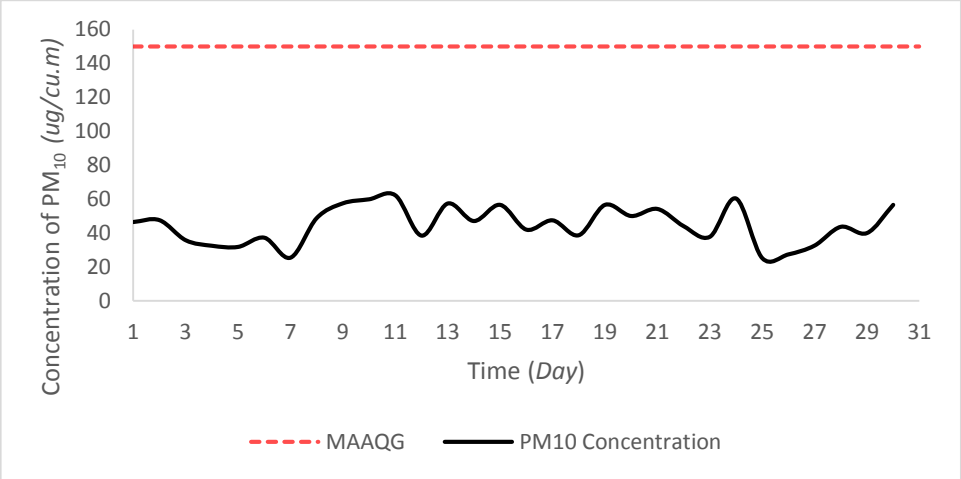


Figure A-133: Concentration of PM_{10} versus time in April 2010 at Station CA0027

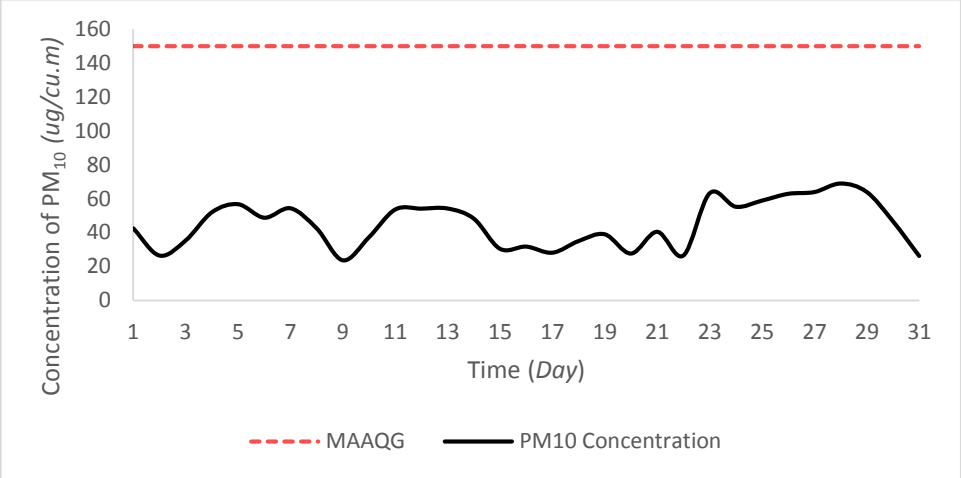


Figure A-134: Concentration of PM_{10} versus time in May 2010 at Station CA0027

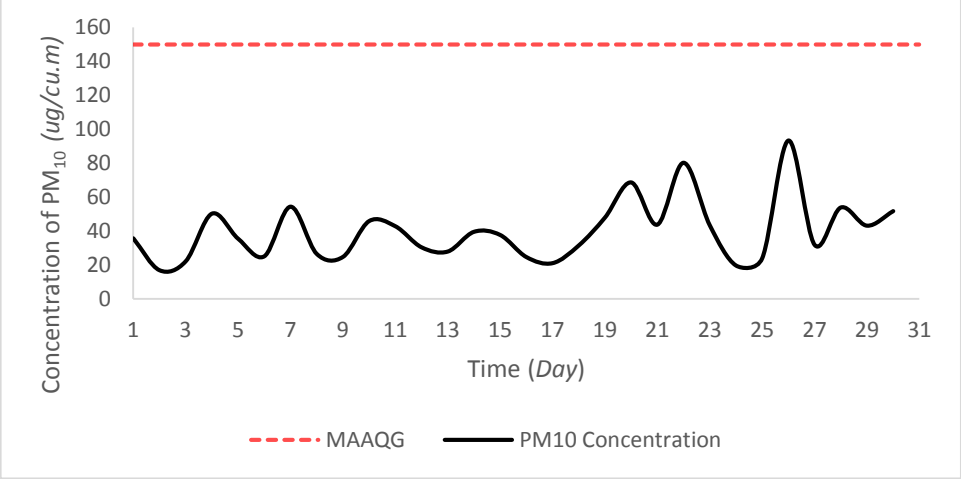


Figure A-135: Concentration of PM_{10} versus time in June 2010 at Station CA0027

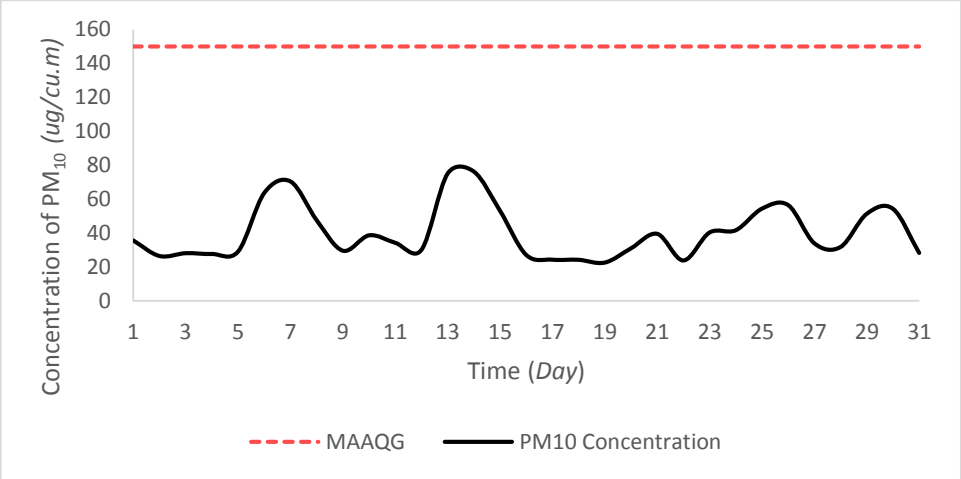


Figure A-136: Concentration of PM_{10} versus time in July 2010 at Station CA0027

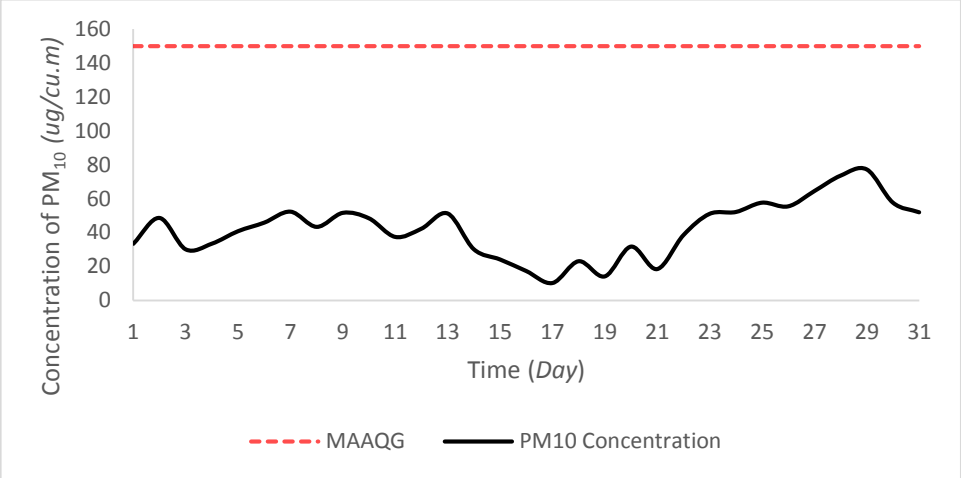


Figure A-137: Concentration of PM_{10} versus time in August 2010 at Station CA0027

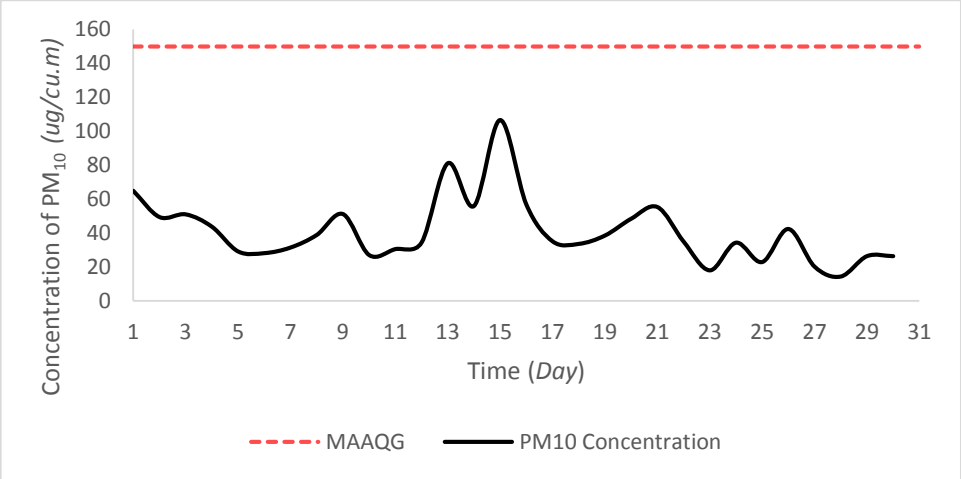


Figure A-138: Concentration of PM_{10} versus time in September 2010 at Station CA0027

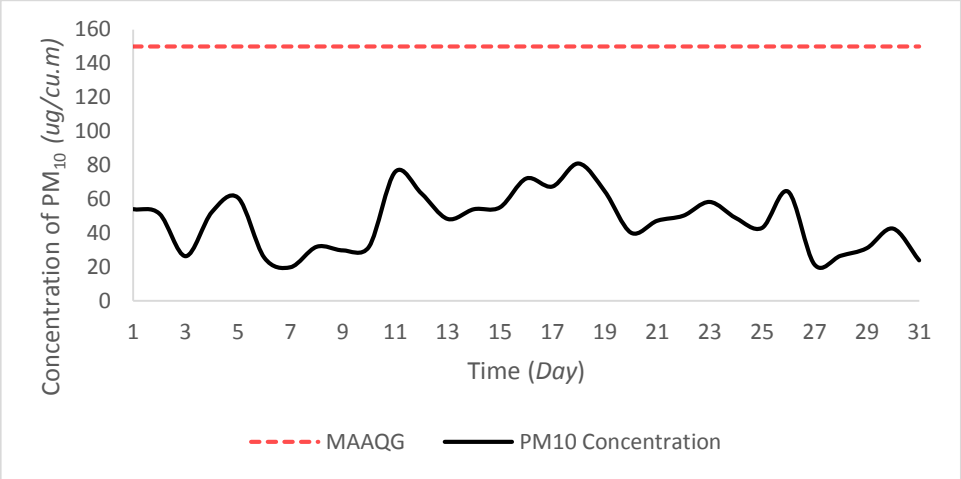


Figure A-139: Concentration of PM_{10} versus time in October 2010 at Station CA0027

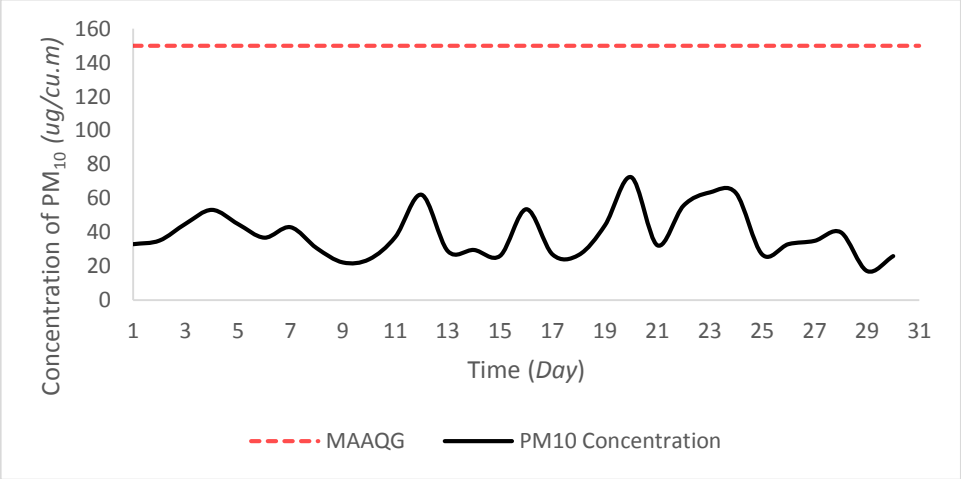


Figure A-140: Concentration of PM_{10} versus time in November 2010 at Station CA0027

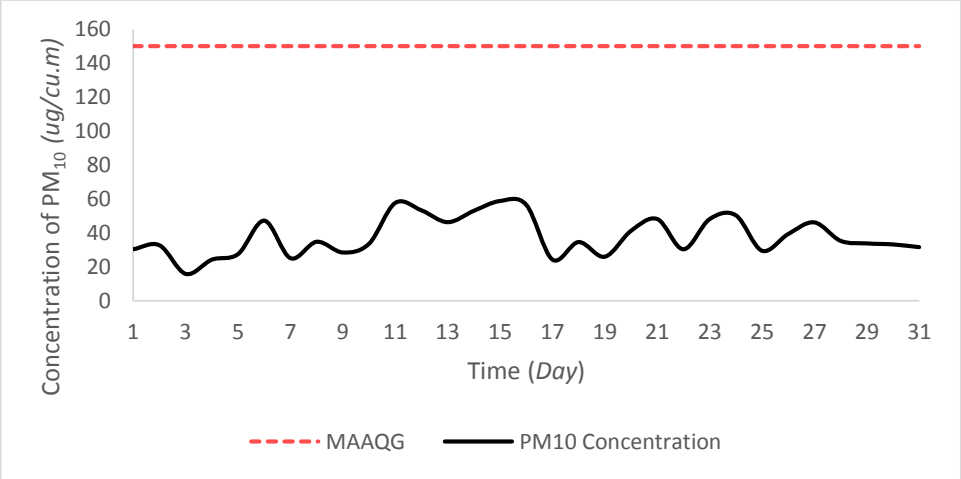


Figure A-141: Concentration of PM_{10} versus time in December 2010 at Station CA0027

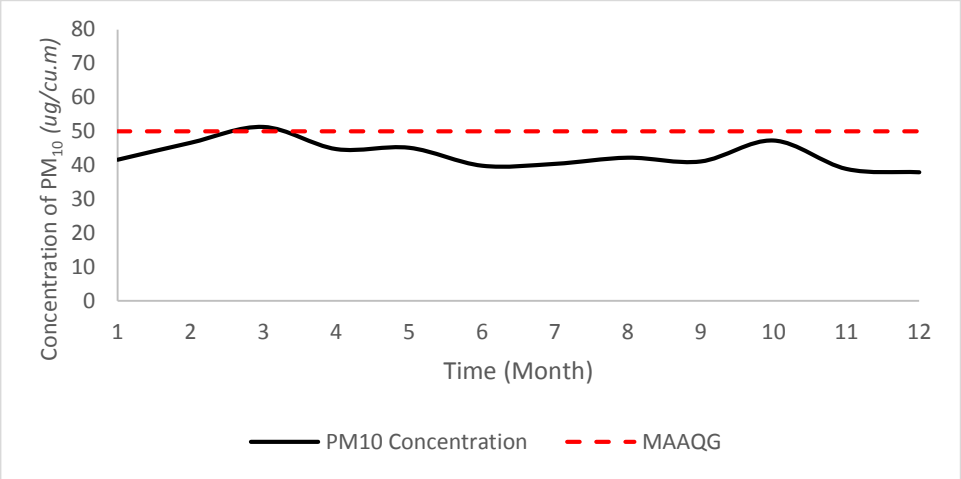


Figure A-142: Concentration of PM_{10} versus time in Year 2010 at Station CA0027

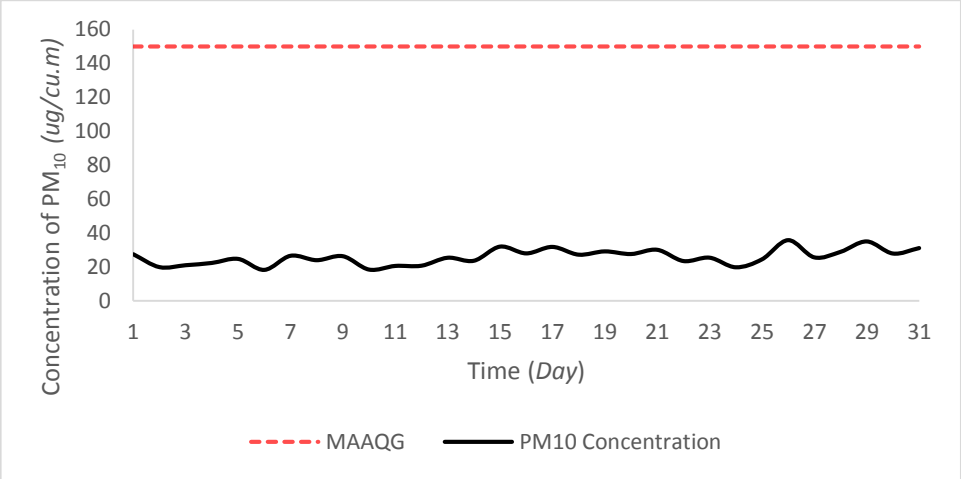


Figure A-143: Concentration of PM_{10} versus time in January 2008 at Station CA0028

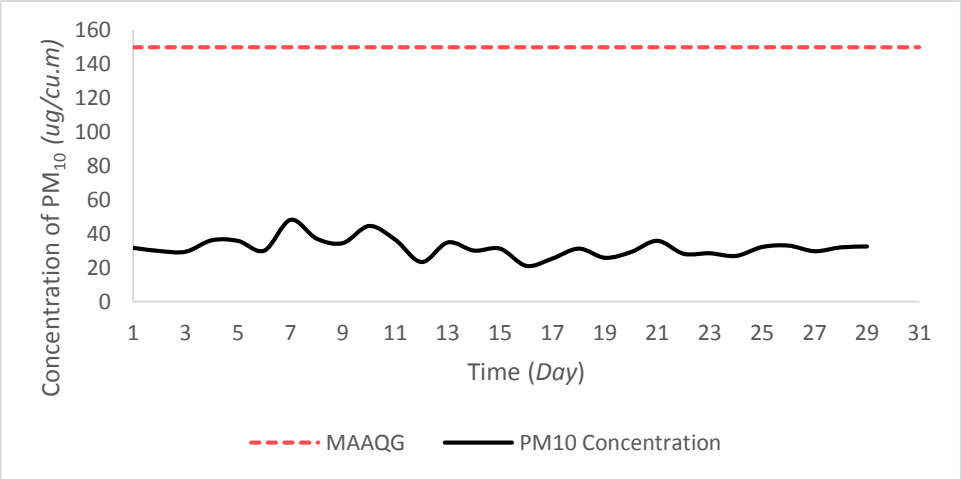


Figure A-144: Concentration of PM_{10} versus time in February 2008 at Station CA0028

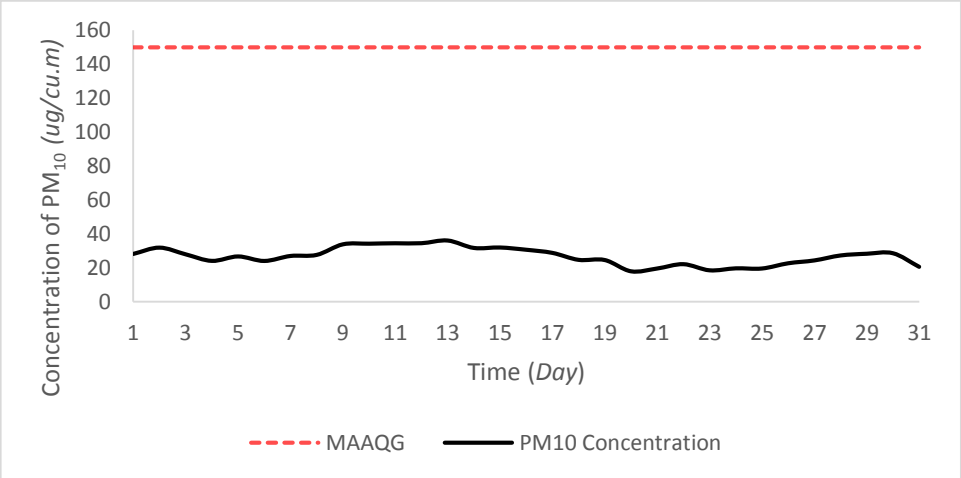


Figure A-145: Concentration of PM_{10} versus time in March 2008 at Station CA0028

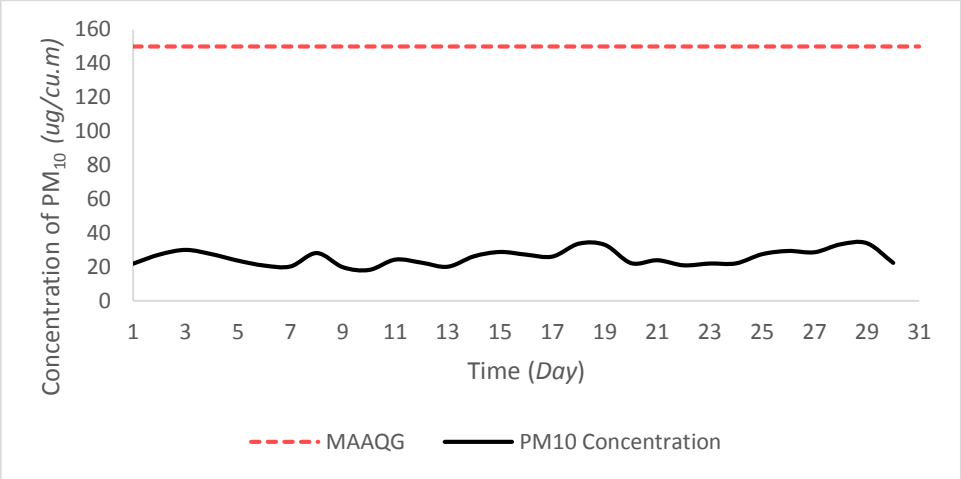


Figure A-146: Concentration of PM_{10} versus time in April 2008 at Station CA0028

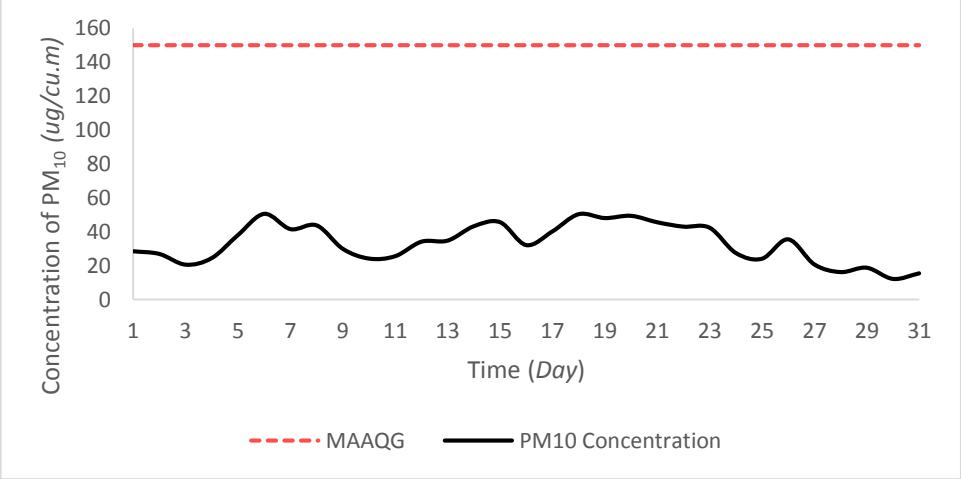


Figure A-147: Concentration of PM_{10} versus time in May 2008 at Station CA0028

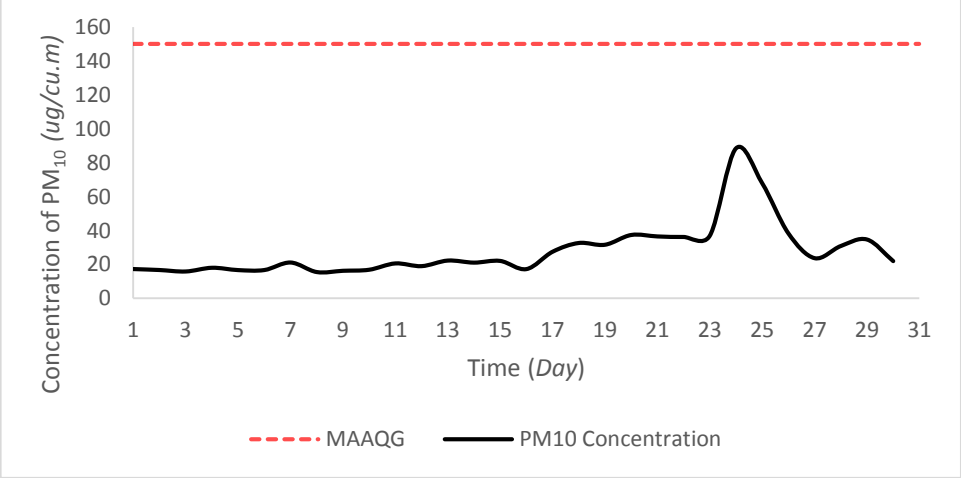


Figure A-148: Concentration of PM_{10} versus time in June 2008 at Station CA0028

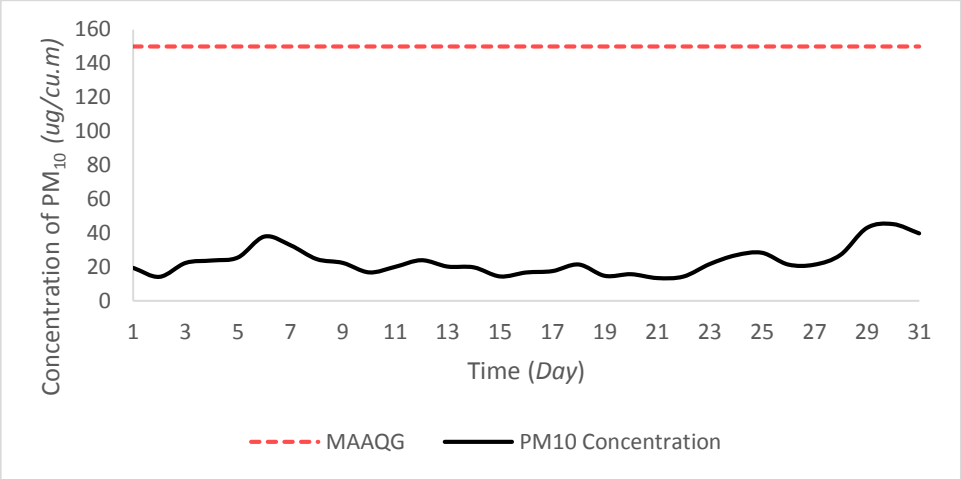


Figure A-149: Concentration of PM_{10} versus time in July 2008 at Station CA0028

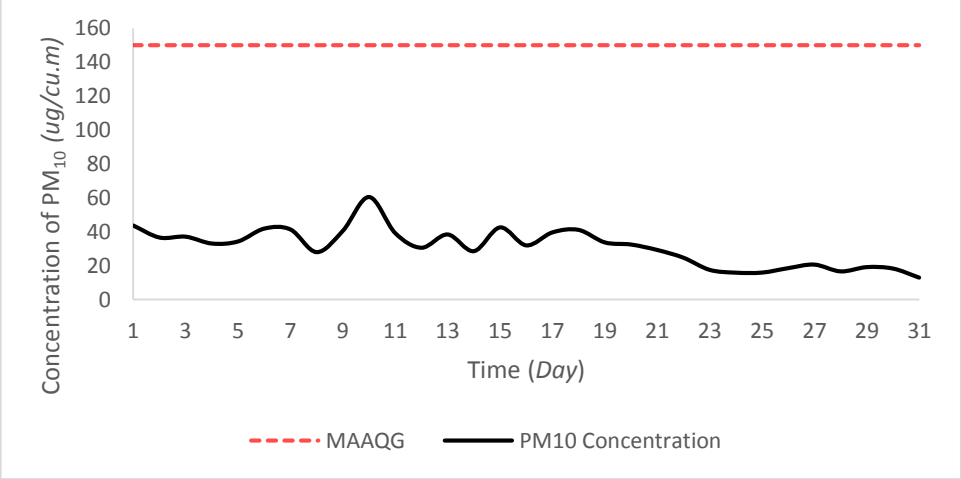


Figure A-150: Concentration of PM_{10} versus time in August 2008 at Station CA0028

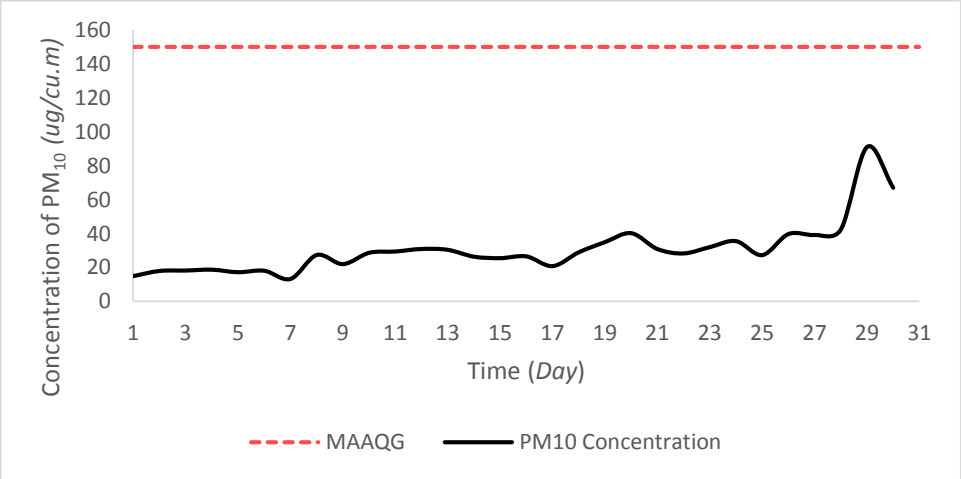


Figure A-151: Concentration of PM_{10} versus time in September 2008 at Station CA0028

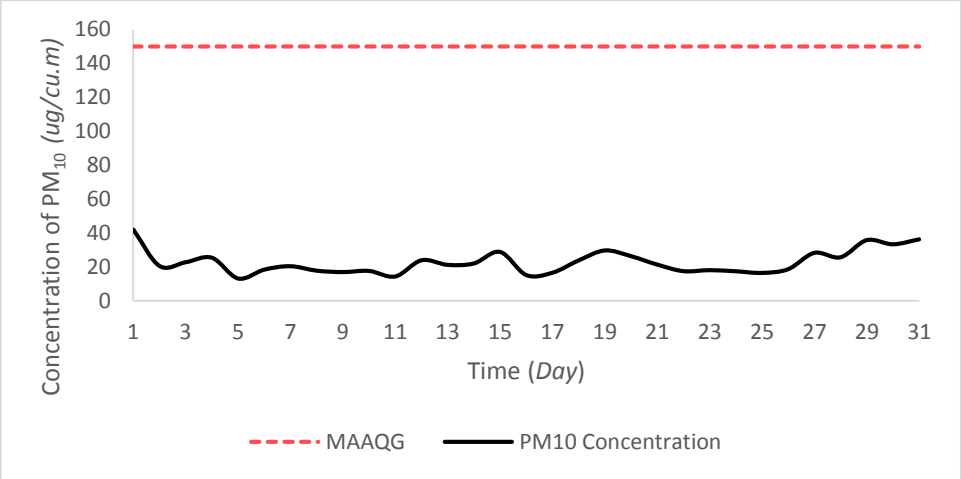


Figure A-152: Concentration of PM_{10} versus time in October 2008 at Station CA0028

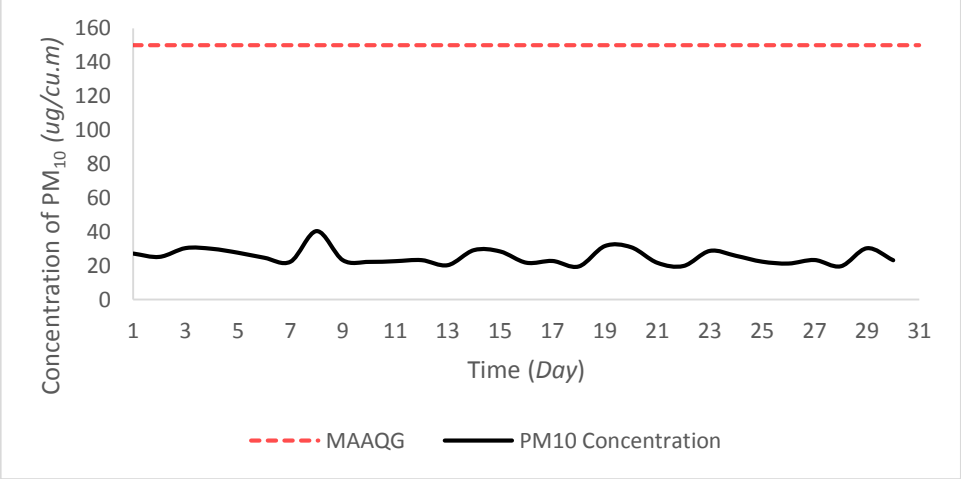


Figure A-153: Concentration of PM_{10} versus time in November 2008 at Station CA0028

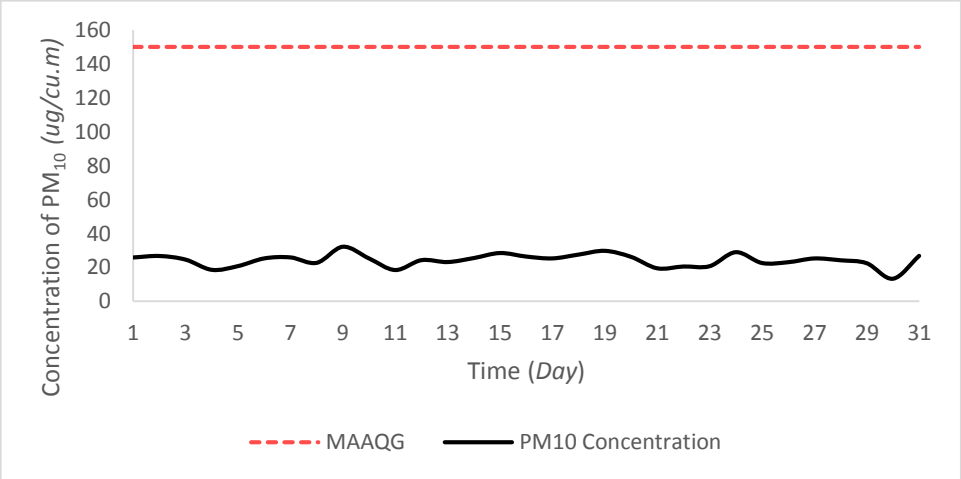


Figure A-154: Concentration of PM_{10} versus time in December 2008 at Station CA0028

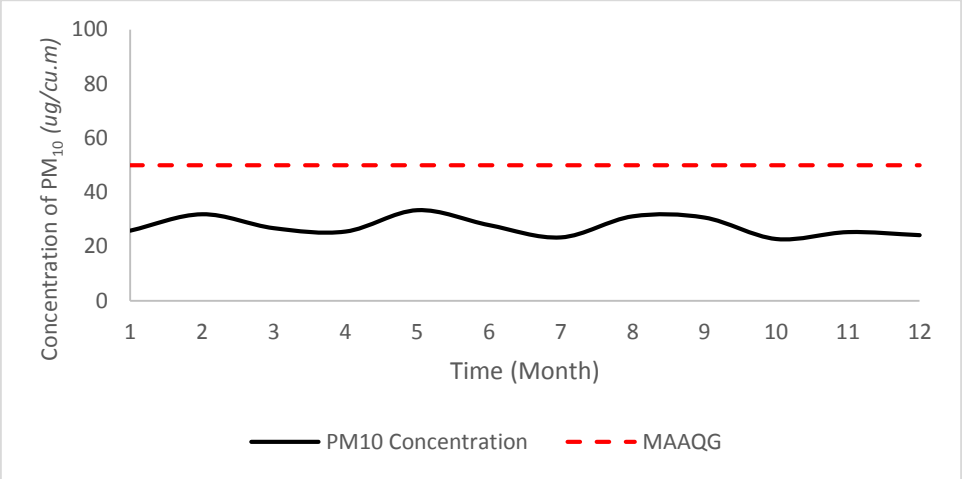


Figure A-155: Concentration of PM_{10} versus time in Year 2008 at Station CA0028

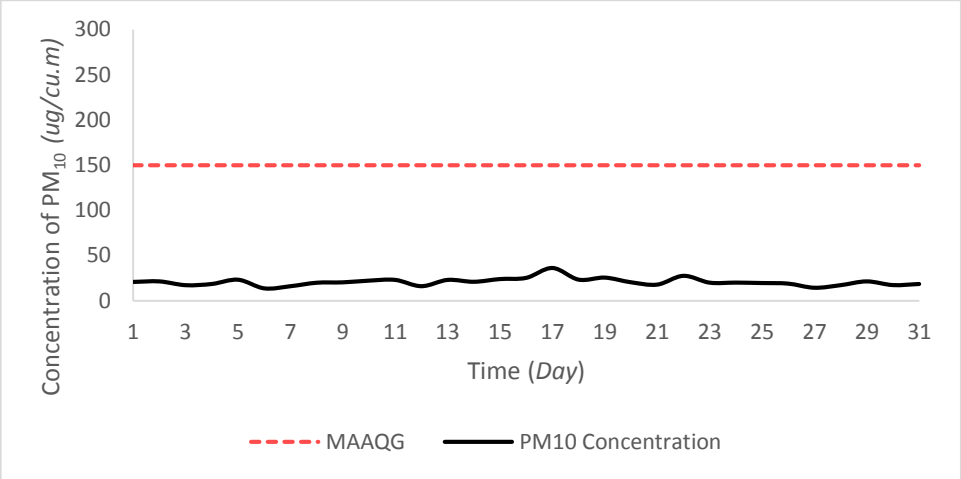


Figure A-156: Concentration of PM_{10} versus time in January 2009 at Station CA0028

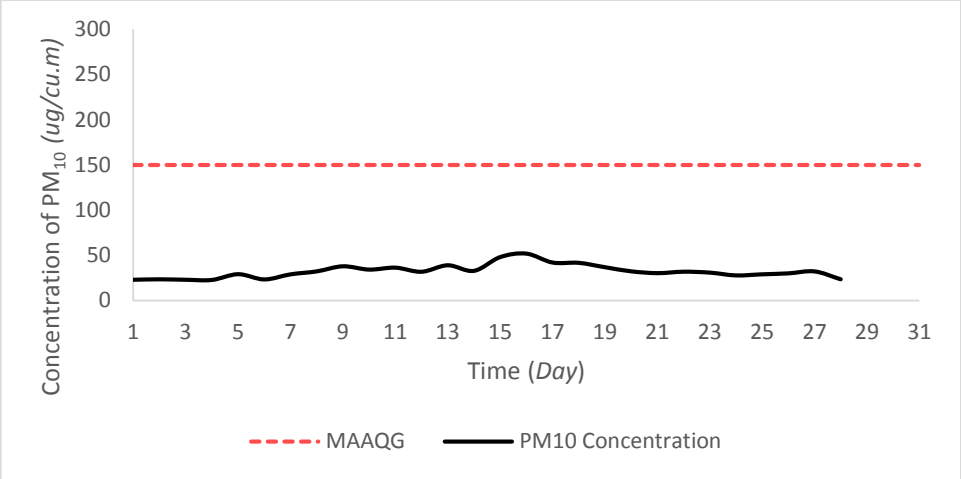


Figure A-157: Concentration of PM_{10} versus time in February 2009 at Station CA0028

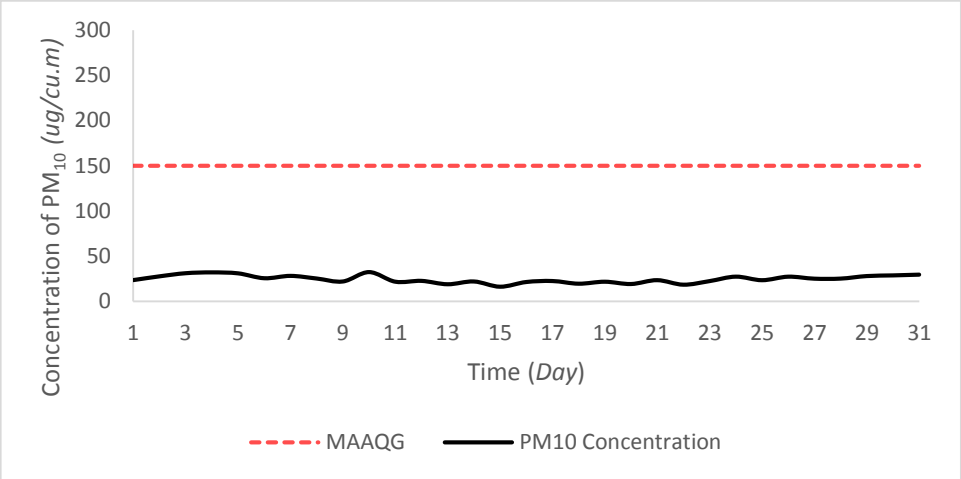


Figure A-158: Concentration of PM_{10} versus time in March 2009 at Station CA0028

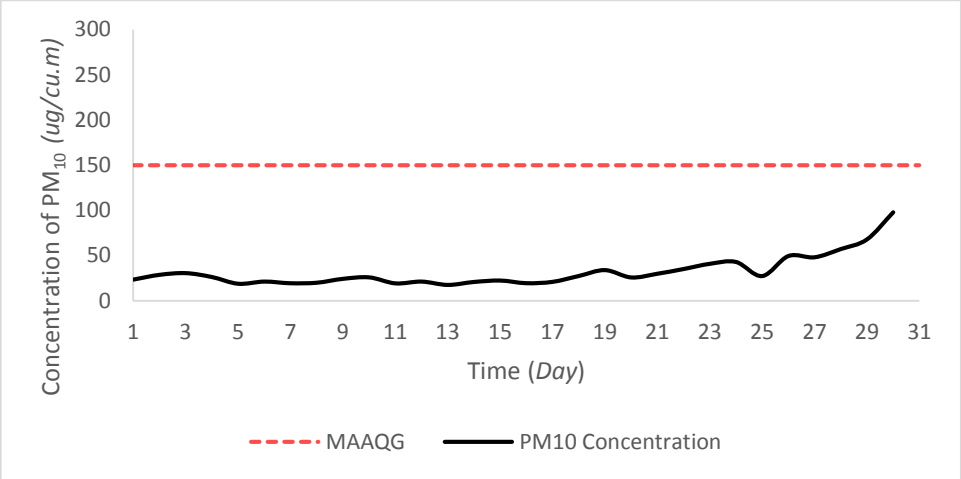


Figure A-159: Concentration of PM_{10} versus time in April 2009 at Station CA0028

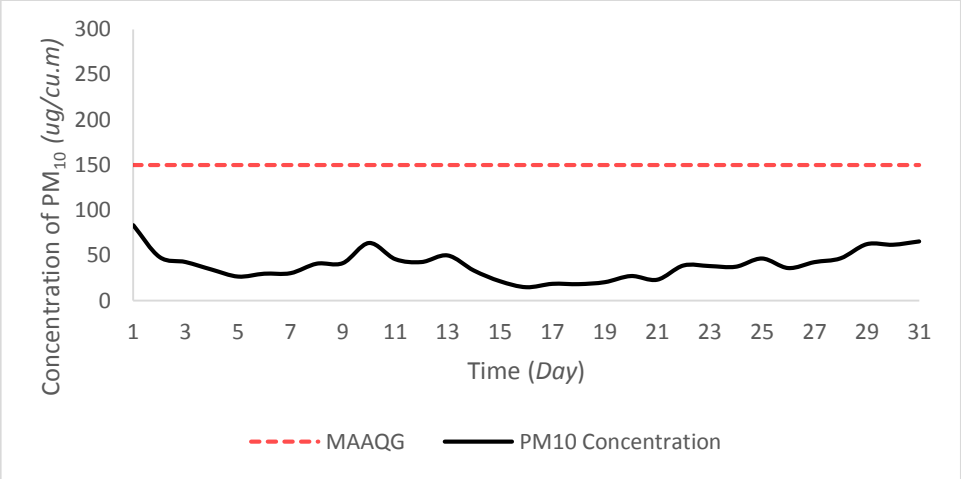


Figure A-160: Concentration of PM_{10} versus time in May 2009 at Station CA0028

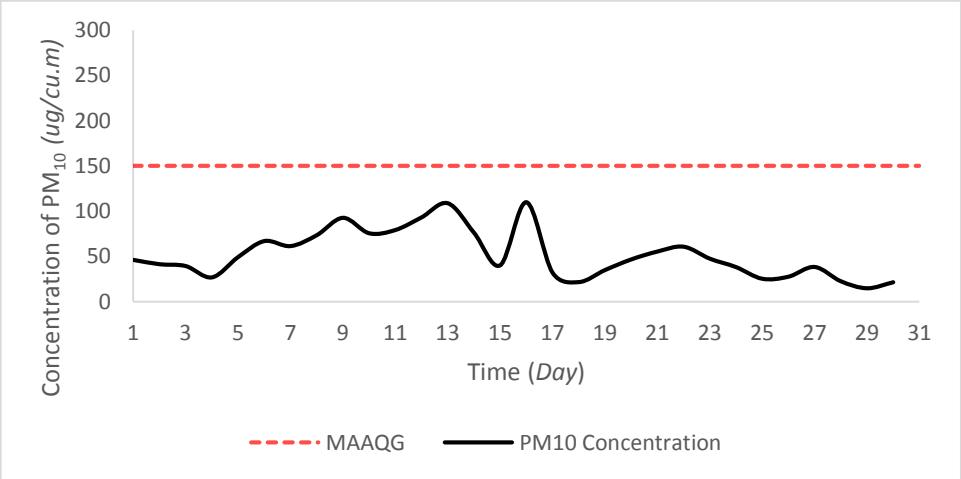


Figure A-161: Concentration of PM_{10} versus time in June 2009 at Station CA0028

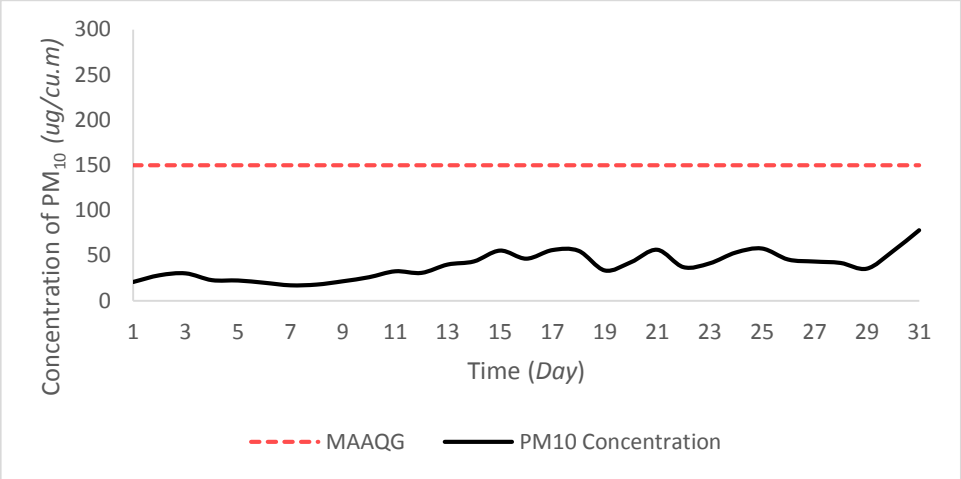


Figure A-162: Concentration of PM_{10} versus time in July 2009 at Station CA0028

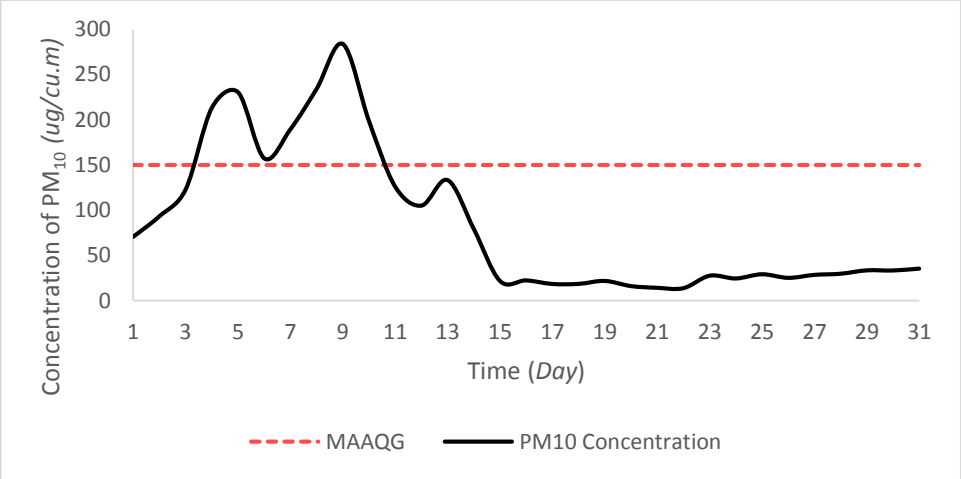


Figure A-163: Concentration of PM_{10} versus time in August 2009 at Station CA0028

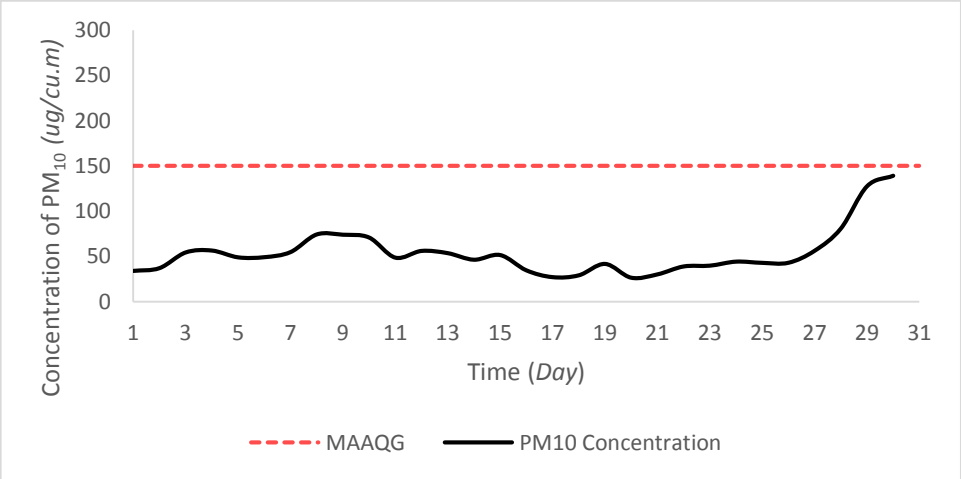


Figure A-164: Concentration of PM_{10} versus time in September 2009 at Station CA0028

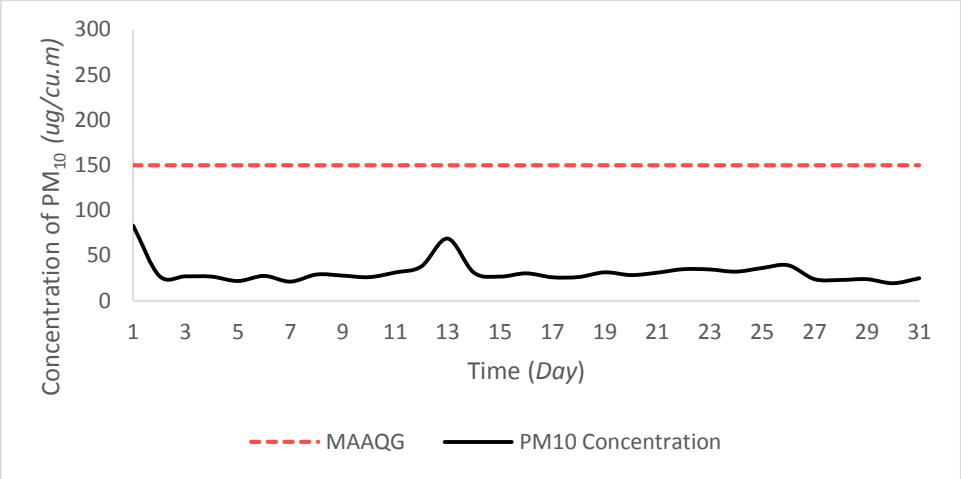


Figure A-165: Concentration of PM_{10} versus time in October 2009 at Station CA0028

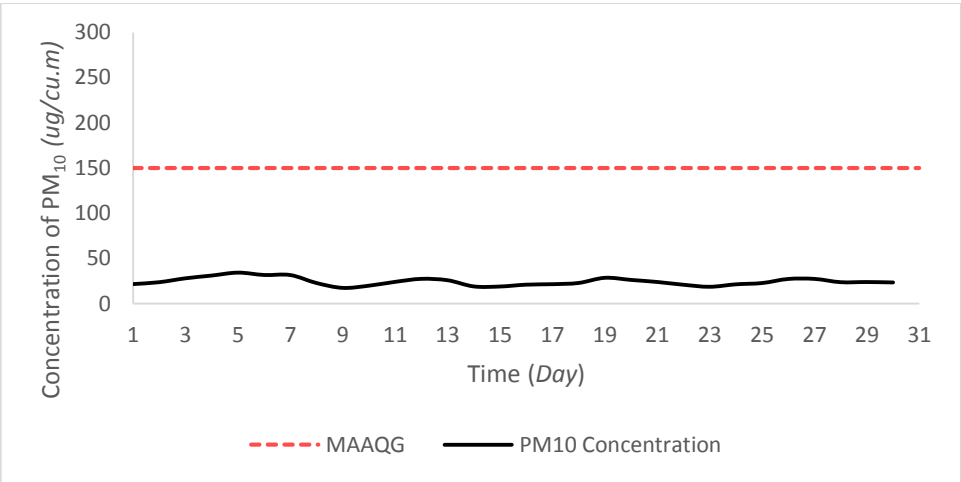


Figure A-166: Concentration of PM_{10} versus time in November 2009 at Station CA0028

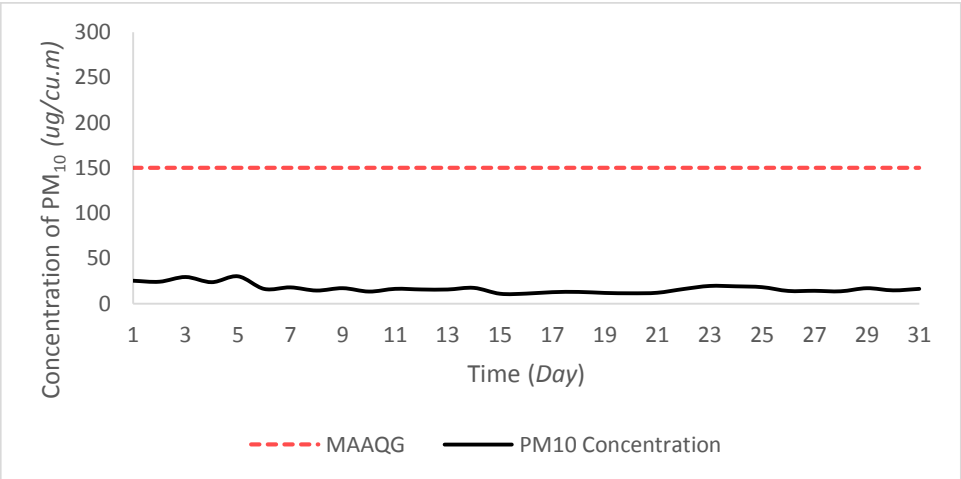


Figure A-167: Concentration of PM_{10} versus time in December 2009 at Station CA0028

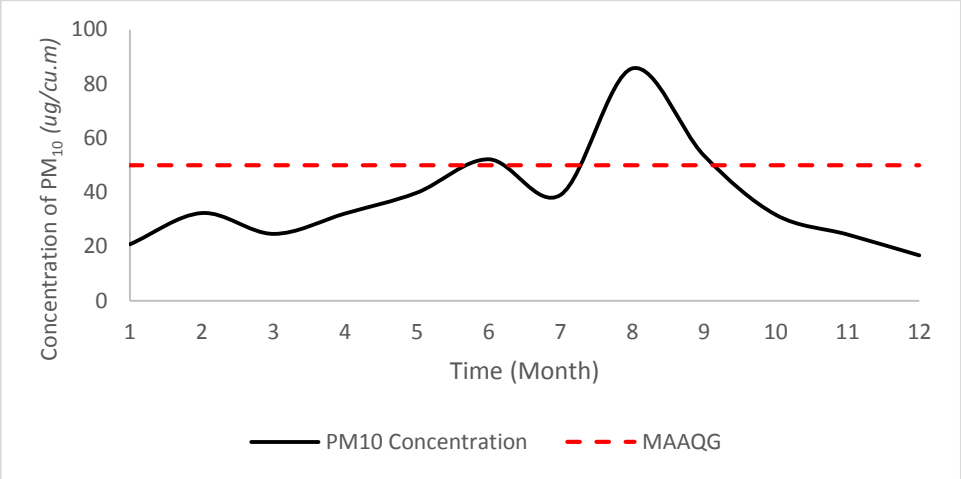


Figure A-168: Concentration of PM_{10} versus time in Year 2009 at Station CA0028

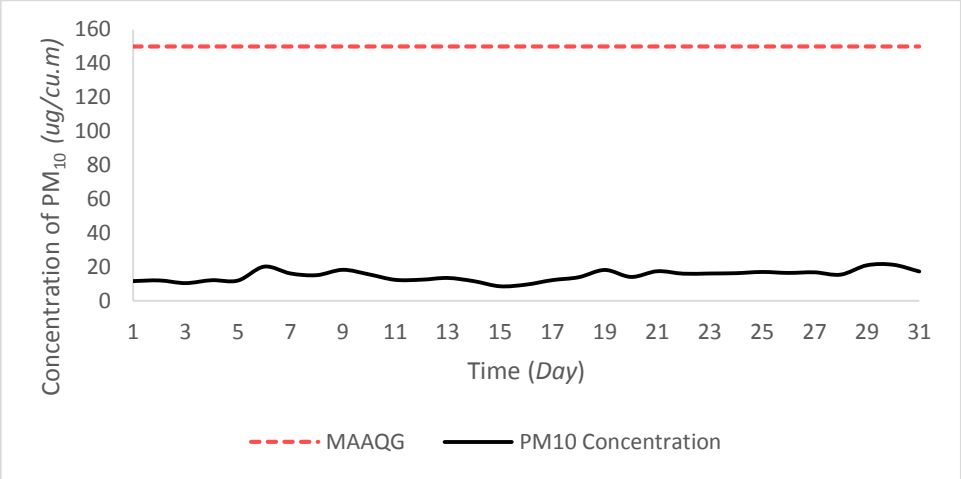


Figure A-169: Concentration of PM_{10} versus time in January 2010 at Station CA0028

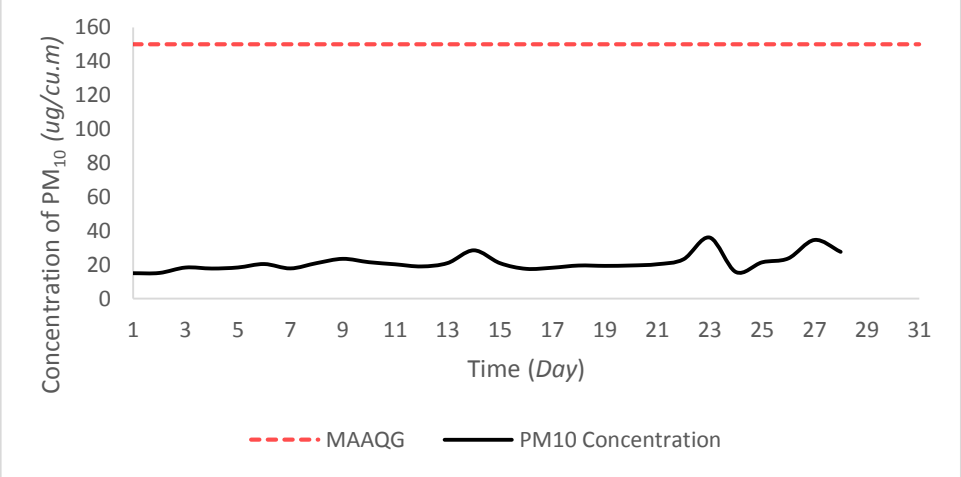


Figure A-170: Concentration of PM_{10} versus time in February 2010 at Station CA0028

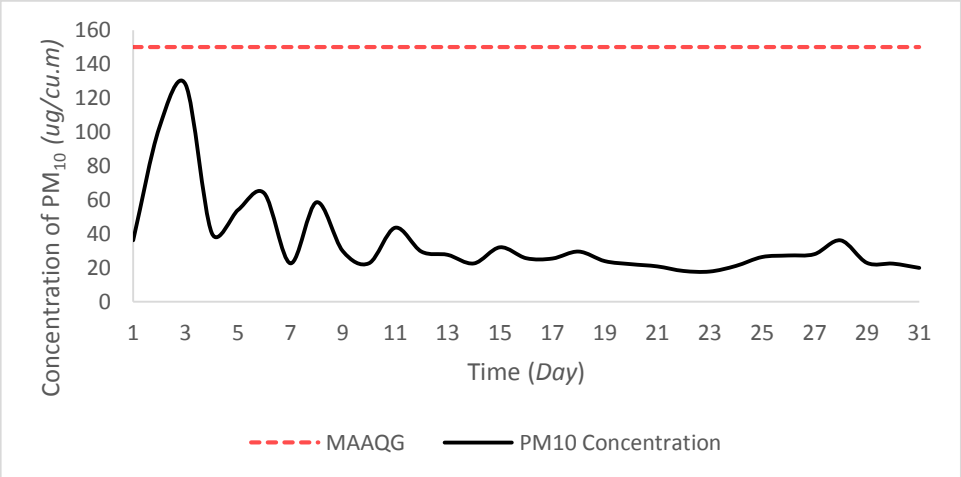


Figure A-171: Concentration of PM_{10} versus time in March 2010 at Station CA0028

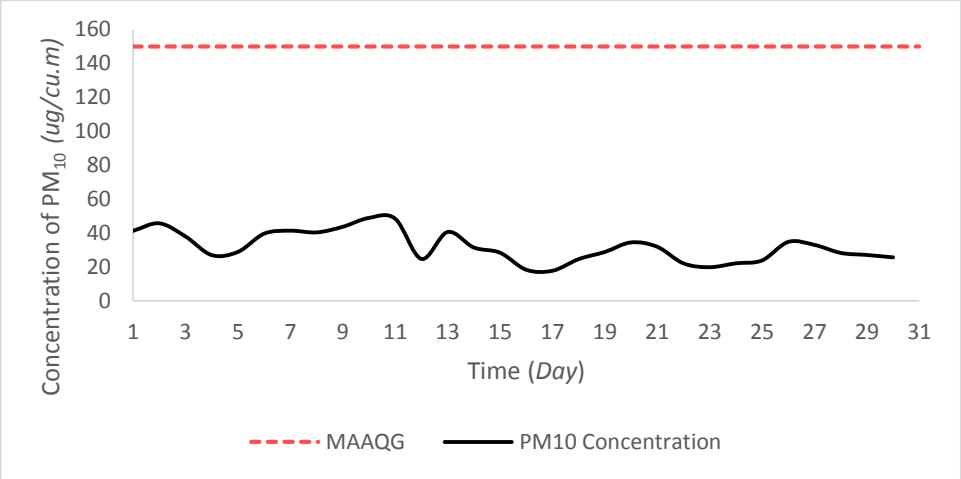


Figure A-172: Concentration of PM_{10} versus time in April 2010 at Station CA0028

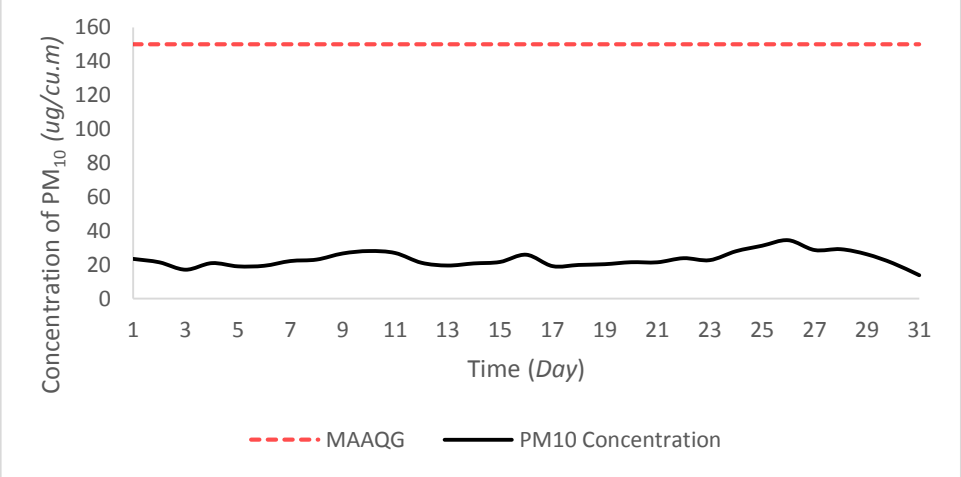


Figure A-173: Concentration of PM_{10} versus time in May 2010 at Station CA0028

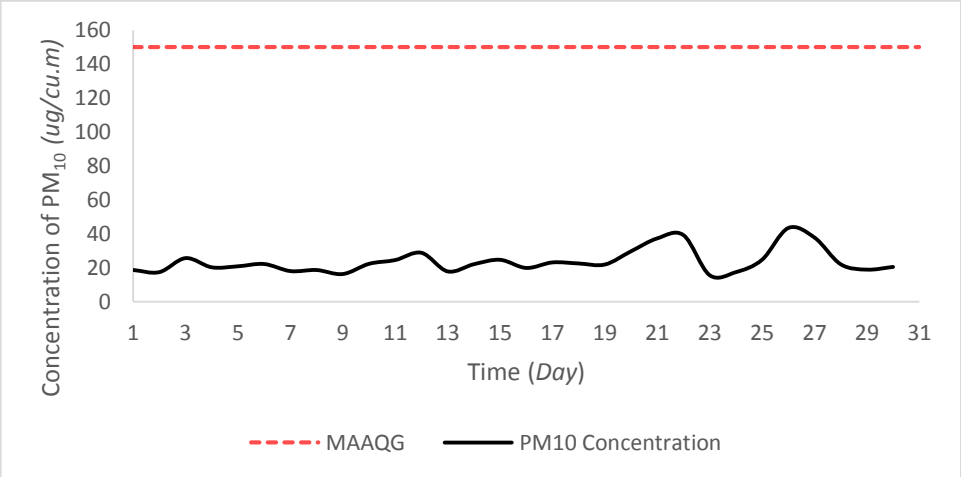


Figure A-174: Concentration of PM_{10} versus time in June 2010 at Station CA0028

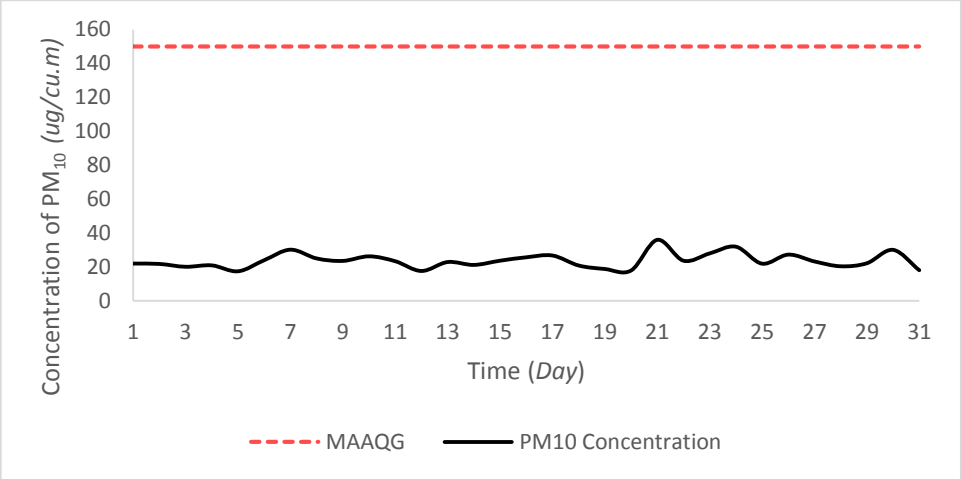


Figure A-175: Concentration of PM_{10} versus time in July 2010 at Station CA0028

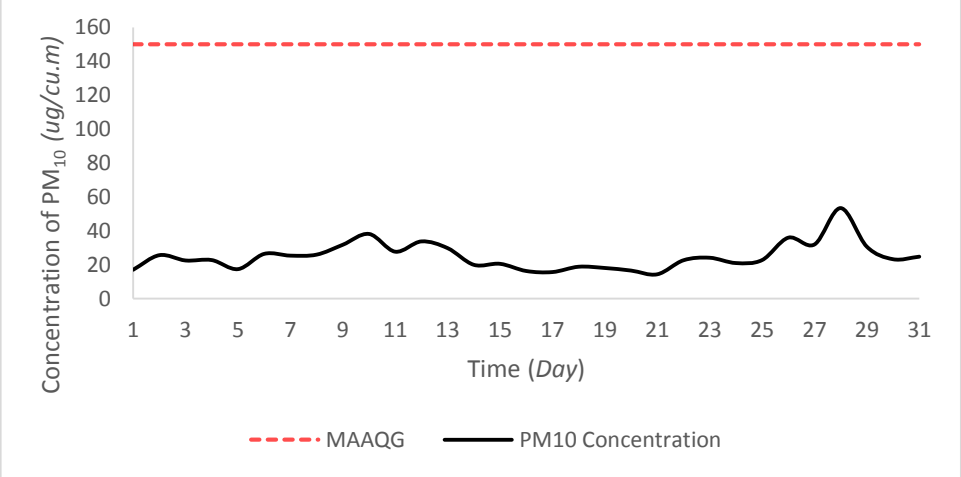


Figure A-176: Concentration of PM_{10} versus time in August 2010 at Station CA0028

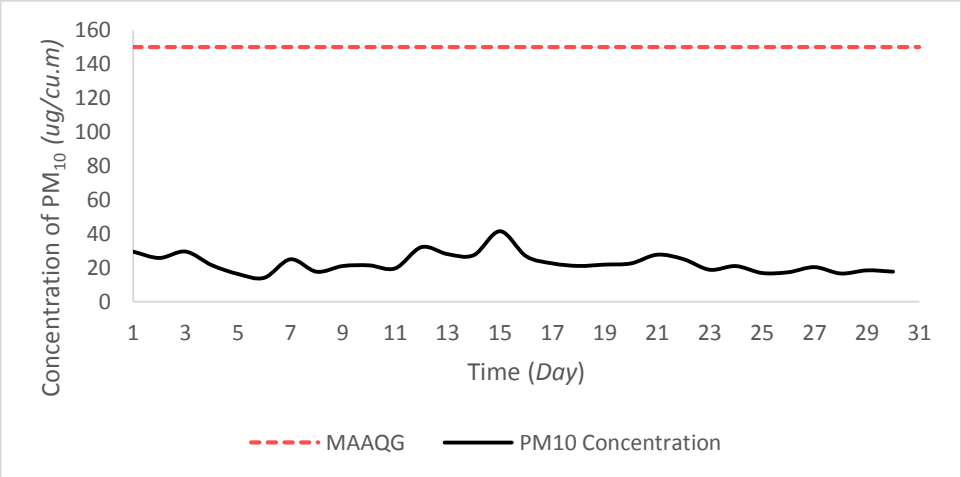


Figure A-177: Concentration of PM_{10} versus time in September 2010 at Station CA0028

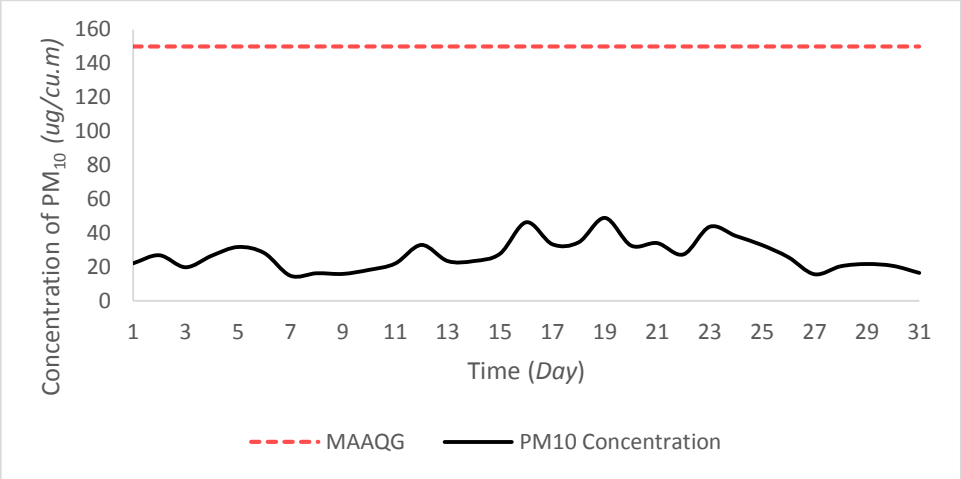


Figure A-178: Concentration of PM_{10} versus time in October 2010 at Station CA0028

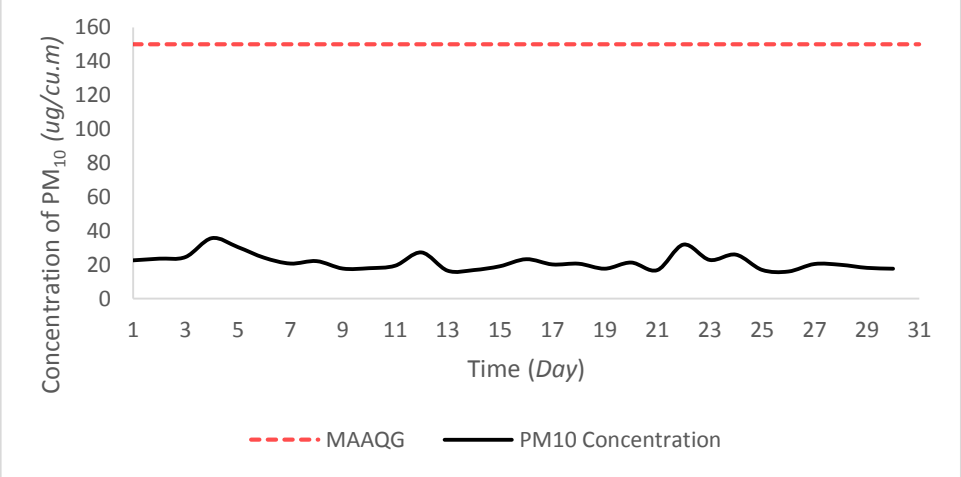


Figure A-179: Concentration of PM_{10} versus time in November 2010 at Station CA0028

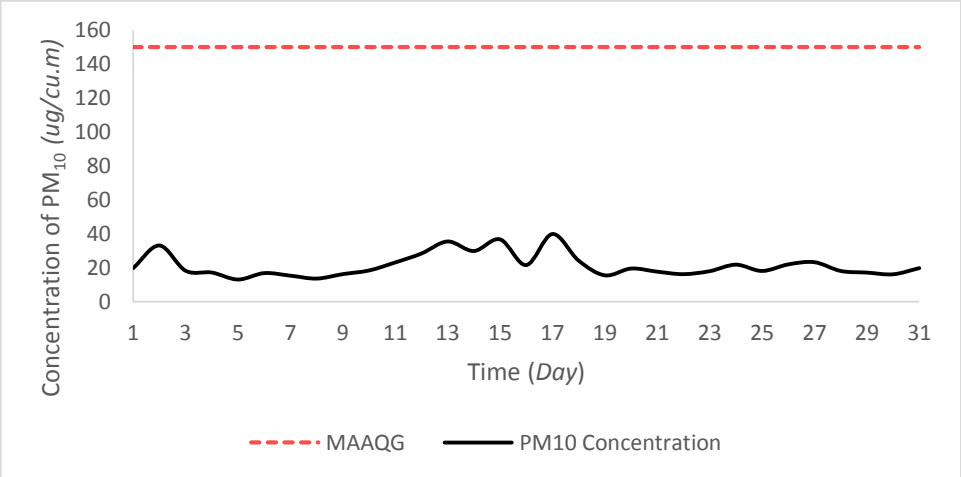


Figure A-180: Concentration of PM_{10} versus time in December 2010 at Station CA0028

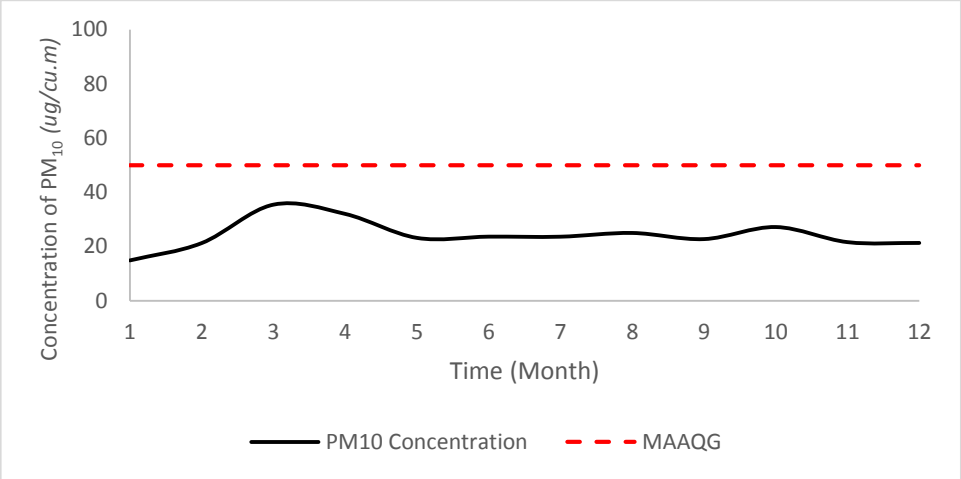


Figure A-181: Concentration of PM_{10} versus time in Year 2010 at Station CA0028